A Case for Missing Salience

in the Attentional Blink

by

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ABSTRACT

A literature search revealed that previous research on the Attentional Blink (AB) has not examined the role of salience in AB results. I examined how salience affects the AB through multiple forms and degrees of salience in target 1 (T1) and target 2 (T2) stimuli. When examining increased size as a form of salience, results showed a more salient T2 increased recall, attenuating the AB. A more salient T1 did not differ from the control, suggesting the salience (increased size) of T2 is an important factor in the AB, while salience (increased size) of T1 does not affect the AB. Additionally, the differences in target size (50% or 100% larger) were not significantly different, showing size differences at these intervals do not affect AB results. To further explore the lack of difference in results when T1 is larger in size, I examined dynamic stimuli used as T1. T1 stimuli were presented as looming or receding. When T1 was presented as looming or receding, the AB was attenuated (T2 recall at lag 2 was significantly greater). Additionally, T2 recall was significantly worse at lags three and four (showing a larger decrease directly following the attenuated AB). When comparing looming and receding against each other, at lag 2 (when recall accuracy at its lowest) looming increased recall significantly more than receding stimuli. This is expected to be due to the immediate attentional needs related to looming stimuli. Overall, the results showed T2 salience in the form of size significantly increases recall accuracy while T1 size salience does not affect the AB results. With that, dynamic T1 stimuli increase recall accuracy at early lags (lag 2) while it decreases recall accuracy at later lags (lags 3 and 4). This result is found when the stimuli are presented at a larger size (stimuli appearing closer), suggesting the more eminent need for attention results in greater effects on the AB.

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Introduction

Attentional Blink Introduction

The attentional blink (AB) is the inability to process a target within a 500 millisecond (ms) period of recovering from processing another target (Olivers, 2007). The AB is defined based on timing between targets, while its relationship with salience is unclear. The current paper will review the concept of the AB and its relationship with timing and salience.

Attentional Blink Applications

Olivers (2007) identified instances in real-life scenarios where the AB may have adverse effects on human interactions, where stimuli rapidly succeed each other. In this example, driving in traffic requires drivers to switch their attention between attending to a cars' break lights, then switching attention to another car activating their turning signal. Trick, Enns, Mills, and Vavrik (2004) argue that a lapse in attention has serious implications. They provide an example where the AB is present while traveling at higher speeds in a car. The driver is expected to see a signal or hazard and react accordingly in a short amount of time. From knowledge of the AB, they are able to determine how long it will take for the driver to switch their attention and act on the hazard. With the implications of the examples provided, as well as others, it is of importance to understand the AB and its causes. With a continued increase in stimuli consumption and speeds of intake, the consequences are clear, and it is important to understand the nature of switching attention. Additionally, Olivers (2007) notes how the AB is linked to many cognitive concepts such as consciousness and perception. He continues that the AB has been linked to many disorders such as depression and Alzheimer's, among others. Understanding the AB and its characteristics will additionally contribute to the understanding of related disorders.

Another area of application is the concept of lag-1 sparing, where people are able to process a second target as long as it is within 200 ms of the first target. Lag-1 sparing will be discussed in more detail later in the paper. Olivers (2007) noted that lag-1 sparing appears to be adaptive in preparing individuals to leap into action. Aston-Jones, Rajkowski, and Cohen (2000) report that lag-1 sparing is an increase in activation and releases neurotransmitter noradrenaline, which is responsible for attentional enhancement. Olivers (2007) suspects this rush of adrenaline allows individuals to react swiftly when it is necessary and aids in performance related to relevant events. Again, understanding the AB and the associated lag-1 sparing can aid in understanding these concepts in relation to their applications.

Exploring the relationships between the AB, timing, and salience will lead to improving the aforementioned real-world scenarios that involve the AB. Specifically, timing has been well explored with the AB, while the AB and salience has been less examined. In order to explore the relationship between the AB and salience, the remaining review will cover the AB characteristics, theories of the AB, working memory (WM) consolidation, salience, and existing relevant literature.

Attentional Blink Definition

Characteristics.

The AB is a phenomenon that derived from interest in time-based attention research, discovered by Broadbent and Broadbent (1987), by Reeves and Sperling (1986), and Weichselgartner and Sperling (1987). It was given the name, the AB, by Raymond, Shapiro, and Arnell (1992).

Olivers (2007) introduced the AB as the inability to process a target within a half a second period of recovering from attending to another target. The AB typically occurs when subjects are asked to attend to multiple targets in a stream of non-targets, within a rapid serial visual presentation (RSVP) (Shapiro, Driver, Ward, Sorensen, 1997).

In the modern version of an AB task, participants are instructed to detect and recall two targets on each trial. The two targets are referred to as target one (T1) and Target two (T2). All stimuli presented in the RSVP stream besides T1 and T2 are considered distractors (Olivers, 2007). Additionally, the distance or number of distractors, referred to as lags, between T1 and T2 vary randomly across trials. The number of lags corresponds to the number of items between T1 and T2 on a trial (Olivers, 2007). For example, a trial in which T2 is presented directly after T1, is called lag 1; when T2 is the third item after T1, the lag is referred to as lag 3 (Vogel et al., 1998).

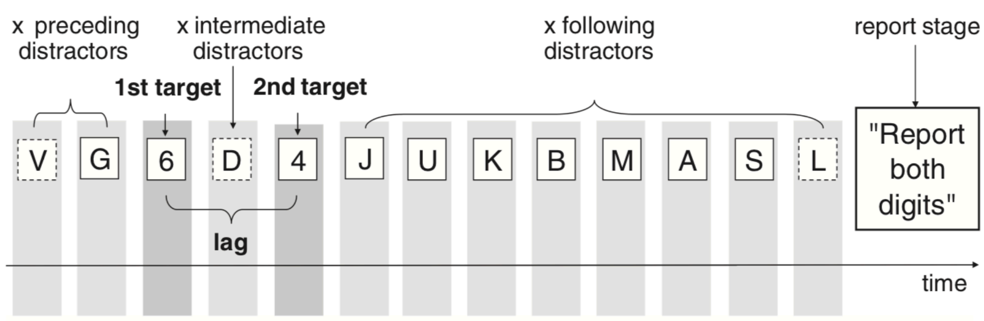

Figure 1. A typical attentional blink task (Olivers, 2007, p. 12).

When participants correctly detect T1, it is followed by a period of time, where the participant is unable to report T2 or that T2 was present. This usually occurs if T2 appears within approximately 500 milliseconds (a range of 200 to 600 milliseconds) of

T1 (Broadbent & Broadbent, 1987; Reeves & Sperling, 1986, Vogel at al., 1998; Shapiro, Raymond, Arnell, 1997; Raymond et al., 1992). The term AB derives from the impairment that would be produced by an eye blink (Raymond et al., 1992; Vogel at al., 1998). T2 is only suppressed when participants attend to T1; T2 can be reported when participants are instructed to ignore T1 (Shapiro et al., 1997). In addition to ignoring T1, T2 can be reported when T1 and T2 are separated by more than 500 milliseconds (Shapiro et al., 1997).

Results Pattern.

Researchers have found that accuracy for reporting T2 becomes considerably more difficult when there is a shorter interval between T1 and T2 (Broadbent & Broadbent, 1987; Raymond et al., 1992; Weichselgartner & Sperling, 1987; Reeves & Sperling 1986). Specifically, accuracy for detecting T2 is at its lowest when it is presented after lag 3 and recovers to be reported when presented from lag six to eight (See figure 2) (Chun and potter, 1995; Maid, Frigen and Paulson, 1997; and Raymond et al., 1992). There is a pattern of results differing from the rest of the findings in T2, where there is an increase in recall directly before the large drop off in recall ability, called lag-1 sparing.

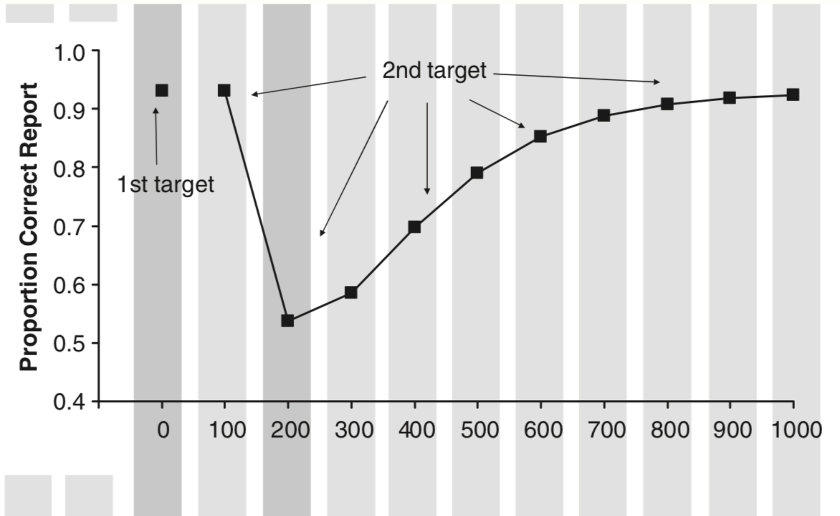

Figure 2. Typical attentional blink results (idealized) (Olivers, 2007, p. 12).

Lag-1 Sparing

Olivers (2007) presented lag-1 sparing as a pattern in the AB results where attention is not reduced but enhanced. Figure 2 shows accuracy for reporting T2 is highest (virtually no AB) at 100 ms after the first target (Potter, Chun, Banks, & Muckenhoupt, 1998; Visser, Bischof, & Di Lollo, 1999). Visser et al. (1999) found lag-1 sparing reported in approximately one half of published reports of the AB. Additionally, accuracy for reporting T2 improved strongly when there was a blank screen (no distractor) presented following T1. Dux and Marois (2009) interpreted this finding as evidence that the distractors in the RSVP stream play a vital role in creating the AB.

Reeves and Sperling (1986) demonstrated lag-1 sparing with a variation of the task. The researchers instructed participants to attend to two simultaneous RSVP streams. One stream contained letters while the other contained numbers. Participants monitored the letter stream until a target appeared, which cued them to switch their attention to the number stream. They were instructed to report as many digits as possible from the number stream. This task enabled them to assess which stimuli participants paid the most attention to. They found results consistent with lag-1 sparing where accuracy peaked first then decreased gradually.

William et al. (2008) and Olivers (2007) present theories for lag-1 sparing, which help further define the nature of the AB. William et al. (2008) suggests T2 is able to enter attention with a metaphor of an attentional gate being opened and triggered by T1, receiving resources limited in capacity.

Olivers (2007) reported the adaptive function associated with lag-1 sparing and the AB. The selection mechanism responds to relevant stimuli (T1) and suppresses irrelevant information (distractors), better preparing humans for life. Rather than viewing the AB as a reduction in attention after an important event (T1), the research of Nakayama and Mackeben (1989) and Reeves and Sperling (1986) support the argument that performance is temporarily enhanced (lag-1 sparing) after viewing something that is relevant.

Both theories support an increase in attention caused by T1. They differ by Olivers (2007) proposing that T1 makes people more vigilant to other important stimuli (T2) when it is within a 100 ms time period (before the AB time period begins). Williams proposed the attention allocated toward T2 is essentially grouped with T1, allowing T2 to be consolidated with T1. The theories of lag-1 sparing directly relate to theories of the AB.

Attentional Blink Theories

For the purposes of this review, theories, models, and hypotheses explaining the AB are divided into theories of vision, attention, and WM. These theories and classifications show the progression of the AB findings and introduce the nature of attention and working memory capacity (WMC) in the AB. The following theories of the AB begin with the idea that the AB occurs due to an inability to perceive targets and progresses into an explanation including WMC consolidation limitations. The following table includes the theories of the AB, their classification in one of three categories (perception, attention, and WM), and a brief description of the theory. Following the table, each theory will be discussed in more detail.

Theory Title	Classification	Year	Brief Description
Inhibition Model	Perception	1992	A theoretical gate opens to allow perception. T1 and T2 can be confused if the gate is open, so must suppress perception of T2.
Attention Dwell Time Hypothesis	Attention	1996	Targets compete for visual resources; only one can reach processing. T1 is better recalled due to being presented earlier.
Two Stage Competition Model of Visual Attention	Attention	2002	T1 is not always consolidated before T2. Targets compete for attention, prior to entering stage two of processing. The first target (T1) enters stage two processing first.
Temporary loss of control hypothesis	Attention	2005	A central processor filters between targets and distractors. The distractors occurring after T1 disrupt filtering, taking longer, becoming susceptible to distractions.
Delayed attentional reengagement account	Attention	2006	Attentional selection uses top down mechanisms. Distractors pause top down processing, resulting in disengagement and the AB.
Distractor Inhibition	Attention	2007	Ability to inhibit distractors is a key to the AB. A suppressed T2 occurs only when distractors are attended to.
Capacity Limited Central Processing	Attention	2009	Targets are in competition with each other multiple times rather than one, suggesting multiple metaphorical bottlenecks in processing.
Interference Theory	Working Memory	1994	T1 and T2 enter WM. They interfere with each other in retrieval;

			competition for weighting (T2 receives less weight) results in unrecallable T2.
Two Stage Model	Working Memory	1995	Stage 1: each item in RSVP is stored. Stage 2: items are encoded and consolidated into WM. T2 must wait until T1 is done being encoded, resulting in decay.
Central Interference Theory	Working Memory	1998	Central processing (encoding in WM and response selection) is limited in capacity. Individuals are slower to respond to the second of two tasks (T2). Limited capacity limits processing of simultaneous tasks.
Gated auto-associator model	Working Memory	2004	Items are selected for recall based on item weighting (decided based on how open attentional gate is). The gate is most closed when WM is busy encoding, with a slow recovery rate.
Corollary discharge of attention movement model	Working Memory	2005	Attention is boosted to T1 and withheld from T2 to prevent interference of T1 while it is being encoded into WM, preventing T2 from reaching WM.
Hybrid Models	Working Memory	2006	Stage 1: stimuli processed. Stage 2: encoding into WM. Distractors are incorrectly consolidated and clog the metaphorical bottleneck in WM consolidation.
Episodic simultaneous type/serial token model	Working Memory	2007	Registering items for recall is limited and suppressing distractors that follow T1 aid in consolidating T1.
Boost and bounce theory	Working Memory	2008	Not due to capacity limitations. Strength of processing is due to stimuli around target. WM must filter distractors in order for targets to reach WM.
Threaded cognition model	Working Memory	2009	Target detection is not possible during WM encoding. When T1 is being encoded, T2 is suppressed to complete T1 consolidation.

Table 1. Attentional blink models and hypotheses.

Perception Theories

Inhibition Model.

Raymond et al. (1992) compared identifying T1 to a gate opening, where the physical characteristics of the target open the gate to allow perception. While the gate is open, it is possible for the following item characteristics to be confused with T1 characteristics. For this reason, individuals must close the gate, suppressing perception at an early level, to reduce interference. The gate is assumed to stay closed until the target has been identified.

Attention Theories

Attention Dwell Time Hypothesis.

Ward, Duncan and Shapiro (1996) developed the attention dwell time hypothesis through investigating the time it takes for attention to shift to targets in varying locations and times. It proposes that the targets are in competition for visual processing resources where only one can reach extended processing. T1 is typically processed and recalled better than T2 due to T1 being processed earlier than T2.

Two Stage Competition Model of Visual Attention.

Potter, Staub, and O'Connor (2002) proposed an extension of the two-stage model. They didn't agree with the notion that T1 received more of the limited capacity resources because of its temporal position. The authors found that when participants were presented with two concurrent RSVP streams and targets were separated by 13 to 53 milliseconds, T2 reporting was higher than T1. When the targets were separated by 100 milliseconds, reporting for T1 and T2 were comparable. Finally, the traditional AB reporting was noticed when targets were separated by 213 milliseconds. Potter et al.

(2002) took this finding to mean that T1 is not always consolidated before T2. With that information, Potter et al. (2002) proposed the two-stage competition model of visual attention. The model states that the targets compete prior to processing, where the first identified target enters stage two first.

Temporary loss of control hypothesis.

Di Lollo, Kawahara, Ghorashi, and Enns (2005) opposed capacity limited models with the temporary loss of control hypothesis. The authors presented participants with an RSVP stream that contained three successive targets. T3 was reported accurately when the three targets were members of the same category. T3 was not reported as successfully when T2 belonged to a different category than the other targets. Di Lollo et al. (2005) proposed that these results are due to a central processor, which filters through targets and distractors, managing one task at a time. On this account, when the targets belong to the same category, filtering is unaltered and can efficiently identify and recall all targets. In addition, if T2 does not belong to the same category filtering takes longer, becoming more susceptible to distraction, than reconfiguration. The distractor and reconfiguration process leads to future stimuli being processed less efficiently. In the case of an AB task with two targets, Di Lollo et al. (2005) explain the AB in terms of disruption in filtering occurring from the distractors following T1, rather than the time between T1 and T2.

Delayed attentional reengagement account.

Various studies led by Nieuwenstein (2006; Nieuwenstein, Chun, van der Lubbe, & Hooge, 2005; Nieuwenstein & Potter, 2006; Nieuwenstein, Potter, & Theeuwes, 2009) believe attentional selection is the underlying reasoning for the AB. When a dual RSVP stream is presented, top down mechanisms are used to allocate attention to stimuli. When there is a distractor in the RSVP, top down processing pauses; the reengagement of top down processing after a short period of disengagement results in the AB.

Distractor Inhibition.

Dux and Harris (2007) proposed an extension of the bottleneck theory, examining whether the bottleneck additionally affects distractor inhibition. To test this, the authors presented subjects with an RSVP stream where half of the trials presented included identical or differing targets that were presented directly before and after T1. The authors believed identical targets presented around T1 would decrease the strength of masking that the distractor would pose. They believe this is true because suppression has already occurred with the earlier, identical character. If this were true, the AB would reduce.

Dux and Harris (2007) found that the AB is attenuated when the items before and after T1 are identical, which led them to believe distractor inhibition is a key component to target selection in an RSVP. Additionally, they found that repetition does not benefit the AB when presented around T2. This led the authors to believe that the suppression is caused by the bottleneck in the AB because the AB only occurs if the distractor receives attention.

Drew and Shapiro (2006) found the same results as Dux and Harris (2007), where the AB is attenuated by repeated distractors surrounding T1. However, they had a different account for its cause. They attributed these results to constructs associated with repetition blindness (RB), representing an impaired ability to report two repeat stimuli that occur within 500 milliseconds of each other (Kanwisher, 1987). Kanwisher (1987) reported that the RB is not due to the distraction of T2, rather the individual is not registering the two targets as distinct objects. This suggests that more research is needed to understand the mechanisms behind the repeated target results.

Capacity Limited Central Processing.

There is debate regarding the number and location of bottlenecks (Dux and Marois, 2009). Awh, Serences, Laurey, Dhaliwal, Van Der Jagt, and Dassonville (2004) proposed the capacity limited central processing model, where stimuli are in competition for multiple rather than a single processing channel. When the authors tested a face-target followed by a letter or digit, an AB was found. The AB was not found when the order was reversed, where the letter or digit came first and the face appeared second. They hypothesize that face recognition requires information processing that is involved in processing the letter or digit. Conversely, processing the letter or number first requires processing that is not required for facial recognition, allowing for processing of both stimuli. However, Landau and Bentin (2008) question Awh et al.'s (2004) hypothesis, explaining the results they found being due to salience rather than bottlenecks. This suggests that there is room for further research related to salience and its effect on consolidation and resource allocation related to the AB.

Working Memory Theories

Interference Theory.

Shapiro, Raymond, and Arnell (1994) proposed the interference theory. The theory assumes that each item in an RSVP stream is perceived then compared to their selection template. The selection template is their target that they are searching for. They adopt the selection template (targets to search for) by the directions of the task instructing them to search for and recall T1 and T2. The stimuli that most closely match the selection template are registered in visual working memory (VWM). Items that are assigned more weight based on alignment with the selection template are more retrievable for recall. According to Shapiro et al. (1994), both targets (T1 and T2) as well as the item directly following them enter WM. When multiple items are in WM, they interfere with each other and affect the retrieval process. The AB is then developed due to competition for weighting in WM, where T2 receives less weight, subjecting it to more interference from other items. Shapiro et al. (1994) explained the absence of the AB after the 200-500 ms period due to VWM resetting. This suggests after a certain amount of time, VWM flushes information when there has been no demand.

Two Stage Model.

Chun and Potter (1995) contested Raymond et al.'s (1992) gating theory when they found an AB when targets were categorical rather than perceptual. Instead of instructing participants to find a different colored target within distractors, they instructed them to find targets that were a different character than the distractors, which were the same color. This led them to believe that the AB exists even when there is not a competition among features (between the color and identity). Additionally, this finding demonstrated that the AB did not occur from task switching between letters because the letters both required identification.

Based on these findings, Chun and Potter (1995) proposed the two-stage model. In stage one, stimuli are stored for each item in the RSVP stream. The stored stimuli are subject to decay and overwriting from additional stimuli in this stage.

Stage two of the model includes encoding and consolidation into WM. Once stage one is complete and targets are identified, stage two begins. Stage two explains where the

AB occurs, due to capacity limitation. Chun and Potter (1995) proposed that the AB occurs when T1 is being encoded in WM and T2 is presented in close proximity. T2 must wait until T1 is finished being encoded, which produces greater susceptibility to decay.

Central Interference Theory.

Jolicoeur (1998) proposed the central interference theory, which is similar to the two-stage model. In the central interference theory, central processing is responsible for encoding in WM and response selection, which is limited in capacity. Jolicoeur (1998) proposed that the explanation of the AB is related to the psychological refractory period (PRP). The PRP reflects slower responding to the second of two sensory-motor tasks because the time for the start between stimuli is reduced. The PRP is thought to occur because of limited capacity, preventing simultaneous tasks to be completed. Jolicoeur (1998) tested this by running an AB task which instructed immediate response for T1. This requires overlap between responding to T1 and encoding T2. Results showed that the AB was larger when immediate response to T1 was required. The AB was even larger when T1 reaction time increased. In total, Jolicoeur's (1998) findings provide evidence supporting the fact that AB is increased by the response selection to T1 (Dux and Marois, 2009).

Gated auto-associator model.

Chartier, Cousineau, and Charbonneau (2004) formed their gated auto-associator model by instructing participants to attend to an RSVP stream with green digit distractors and two red digit targets. The authors establish that stimuli are perceived and evaluated with two methods. One includes identifying the numbers which are then processed through WM. Method two includes comparing the stimuli color to the target color.

According to Chartier et al. (2004), the process starts with stimuli perceived and maintained in the auto-associator; in this step items are selected for recall. The weighting comes from how open the theoretical attentional gate is when the item is entered into the auto-associator (higher weighting occurs with a more open gate). In the particular case of the author's color study, gating openness is determined based on color comparison of the target and template. The gate is most closed (where the AB occurs) when WM is busy encoding another item, which has a slow recovery rate.

Corollary discharge of attention movement model.

Fragopanagos, Kockelkoren, and Taylor (2005) describe model as matching stimuli with an object map. An object map is similar to a selection template, pre-determined targets to search for. After the stimuli is matched to the object map, the item reaches WM and becomes consciously available. The authors believe there is an inverse model controller (IMC) that boosts attention directed at items that are in the object map and into WM. With that, the AB occurs when a boost of attention is withheld from T2 to prevent interference with T1, while it is being encoded. This prevents T2 from reaching WM for later recall.

Hybrid Models.

In a hybrid of previously established two stage and interference theories, Vogel et al. (1998; Sergent, Baillet, & Oehaene, 2005; Vogel & Luck, 2002) examined event related potential's (ERP's). The P-300 component in the ERP's are suggested to reflect WM updating (Donchin, 1981; Donchin & Coles, 1988). The researchers found that the

P-300 wave was not present during missed T2 targets. This led the authors to believe that the T2 did not enter WM during the AB, suggesting that missed T2 targets do not enter the WM store. To explain their results, Vogel et al. (1998) combined the two-stage and interference theories.

The premise of this model suggests two processing stages. The first stage includes stimuli being processed, then encoded into VWM for the second stage. How closely a target matches the target template determines whether the item will be entered into the second stage of processing. Distractors in the first stage, near T2, can be incorrectly consolidated. With this, the AB is expected to be due to bottlenecking in WM consolidation and interference through distractors (Vogel et al., 1998).

Kawahara, Enns, and Di Lollo (2006) also proposed a hybrid model, combining temporary loss of control and bottleneck models. Their model consists of three factors leading to target accuracy in the RSVP stream. One, differentiating between targets and distractors; two, disruption of T1 encoding; three, bottlenecking in processing when T2 is to be processed.

Episodic simultaneous type/serial token model.

Bowman and Wyble (2007) provided a model combining ideas from temporal attention and working memory. The model builds on the two-stage theory, where the AB occurs due to processes differentiating between objects. All stimuli are conceptually identified but to be recalled must have its identity information bound to WM, providing episodic information. This information includes item position related to other stimuli. Additionally, for stimuli to reach a recallable stage in working memory, the item must be enhanced by target detection. The AB occurs because registering items for recall is limited in capacity and can be suppressed due to interference from other targets. The authors classify the AB as an unconscious perceptual strategy, allowing participants to process T1 by suppressing following targets, to aid their limited capacity.

Boost and bounce theory.

(Olivers & Meeter, 2008) proposed a theory with two stages: the sensory processing stage and WM stages, where the AB does not occur due to capacity limitations. With sensory processing, perceptual features such as color and high-level representations, such as categories, activate. According to their theory, the strength of processing items is due to the stimuli around the target (distractors).

In this theory, WM plays several roles. One role is maintaining instructions and task orientation while establishing attention. Another role is retaining representations of targets that will be reported. The final role is considered most important by the authors. WM must filter targets and distractors in order to process targets that are to be recalled. In an example, all distractors appearing before T1 must be filtered out from accessing WM. This process enhances the ability for T1 to access WM and be recalled.

Threaded cognition model.

Taatgen, Juvina, Schipper, Borst, and Martens (2009) propose that the AB occurs due to T2 being blocked while T1 is being consolidated. The authors note that the model includes that identifying targets and consolidation can work simultaneously but target detection is not possible while encoding in WM is occurring. The AB is explained due to participants adopting a suppression strategy while T2 appears, in order to complete consolidation of T1. Similar to the previous models, the authors suggest that T2 is suppressed during processing; however, the current model suggests that there are not limitations in capacity, just an unnecessary protection that is occurring during the AB.

Theories Discussion

Dux & Marois (2009) discuss an overall comparison of the AB models, stating that a majority of the proposals include an account for the AB and lag-1 sparing as well as a consistent view of processing the RSVP stream. Additionally, they note that each model or theory includes at least one of many characteristics that overlap between them. A comparison more specific to the current author's research goals examines the role of WM in the varying models and theories presented about the AB.

Dux and Marois (2009) identify two common characteristics among models, relating to WM. One is the attentional depletion that occurs when T1 is encoded in WM. This commonality is mentioned in bottleneck theories, hybrid models, the global workspace model, gated-associator model, corollary discharge of attention movement model, attention cascade theory, and episodic simultaneous type/serial token model (Dux & Marois, 2009). An additional commonality among models associated with WM is the competition between targets and distractors when items are to be retrieved from WM. This is seen in the interference theory.

A gap in the literature relating to the AB and WM is the topic of salience. As mentioned, Awh et al. (2004) reversed the order of the AB with faces and digits and did not find the AB effect. Landau and Bentin (2008) questioned whether their finding was due to salience. Exploring salience further may provide some AB explanations and implications for WM as well as its role in the AB. Finally, a better understanding of WM and consolidation will contribute to a better understanding of the AB and its characteristics as well as causes.

With a high prevalence of WM consolidation or encoding in AB theories, it is useful to understand the basics of WMC as well as the characteristics of WM consolidation. Exploring the characteristics of WM consolidation will aid in recognizing inconsistencies, strengths, and weakness in the AB literature as well as its relationship to salience within the AB.

Working Memory

Working Memory Capacity

With the presence of WM consolidation and consolidation limitations in the AB models and theories, it is useful to explore the understanding of WM and consolidation in previous literature. Baddeley (2010) describes WM as a system that is used for reasoning, comprehension and learning. WM keeps items that are to be attended to in mind. Unsworth, Schrock and Engle (2004) refer to WM as being composed of the ability to control and direct attention toward goal stimuli while distractors are present.

Vogel & Luck (2002) identified two key components to visual working memory capacity (VWMC), especially as they pertain to the AB. Limitations in VWM, which are assumed to be the cause of the AB, include a limited capacity and consolidation limitations. The VWM system is estimated to have a capacity of three to four items (Sperling, 1960; Vogel, Woodman, & Luck, 2001). Additionally, consolidation in a durable and recallable form requires attentional resources and is a slow process (Jolicoeur & Dell'Acqua, 1998; Potter, 1976).

Working Memory Consolidation

WM consolidation includes transforming short term and impermanent stimuli into long lasting representations, accessible by WM (Vogel & Luck, 2002). Many studies have found that consolidating information into WM is demanding temporally and cognitively (Chun & Potter, 1995; Jolicoeur & Dell' Acqua, 1998; Potter, 1976; Vogel et al., 1998). Irwin (1996; Luck & Vogel, 1997; Vogel et al., 2001) suggested that the VWM holds three to four items and within the same mechanism, consolidation and maintenance must coexist. Additionally, as the amount of information to be remembered increases, the time that it takes to be consolidated increases (Gegenfurtner & Sperling, 1993; Phillips & Christie, 1977; Potter, 1976; Shibuya & Bundesen, 1988; Jolicoeur & Dell' Acqua, 1998). Woodman and Vogel (2005) suspect that VWM is not affected by maintenance that is occurring simultaneously. But maintenance does decrease the amount of stimuli WM can consolidate simultaneously. They hypothesized that consolidation should be less efficient when WM is maintaining. In contrast, the researchers found that participants were able to encode the same amount of information and the rate of consolidation was identical while maintaining versus not maintaining any other information in WM. They took this to mean that consolidation is not affected by maintenance, which led them to believe VWM is a two-step construct of partitioning VWM resources and consolidating stimuli.

The first step in partitioning resources involves evaluating capacity available to correctly partition the resources. This includes distributing the resources among current and new items. Once partitioning is completed, items are available to be consolidated, which is unaffected by concurrent maintenance and only affected when resource capacity in VWM is exceeded. In total, Woodman and Vogel (2005) concluded that consolidation and maintenance share a capacity store but are independent processes.

The proposal of a stage-like process occurring in VWM is consistent with Baddeley's (1986) proposal that VWM is not a single unit of processes but rather a collection of independent processes collectively making up VWM. Woodman and Vogel (2005) use a real-world example where the VWM system must be, and is advantageous to be, a collection of independent processes. For example, when driving a car and maintaining stimuli in the environment, a driver can identify a new truck moving closer. With this, WM consolidation in the AB must be contingent, to some degree, on target salience, in choosing information to be consolidated and recalled. Due to the relationship between WM consolidation, item selection and salience, it is important to understand what salience is as well as the extent that the AB has been examined in its relationship to salience.

Salience

Characteristics

Salience is the physical distinctiveness of an object, noticed through bottom-up processing. Bottom-up processing is processing the properties of the object first instead of expectations (Itti & Koch, 2001; Treisman, 1988; Wolfe, 1998; Findlay & Walker, 1999; Theeuwes, 2005; Theeuwes, 2004; Treisman, 1986; Treisman & Gelade, 1980). Object properties such as color, orientation, movement, and shape, among others, are examples of physical qualities that make an object distinctive and salient (Wolfe, 1992; Wolfe, 1998). The distinctive object properties are dependent on their relationship with other objects in the scene (Treisman, 1988). In example, in a scene of horizontal lines, a vertical line is more salient than another horizontal line. Contrastingly, in a scene of vertical lines, a nearly vertical line is not as salient and harder to detect (Nothdurft, 2000). Additional examples of salient stimuli include a red line among a scene of green lines, a target moving in a different direction from the rest, and a brighter target among a scene of duller targets (Nothdurft, 2000). Salience and distinctiveness increase as the contrast between the object and the rest of the scene increases.

Object salience affects target detectability as well as eye movements (Nothdurft & Parlitz, 1993). Additionally, object salience drives focal attention (Wolfe, Cave & Franzel, 1989). Target detectability, eye movements, and focal attention, influenced by target salience, affect search time. Nothdurft (1993) found that targets were detected faster when they had a high contrast with the non-target objects in the scene. When the targets had more contrast, the target became more attractive and was immediately found, independent of scene size.

Salience and Working Memory

According to the model of attention, called the biased competition model, there is a competition between targets to gain perceptual and response system resources (Desimone & Duncan, 1995). WM biases the focus of attention to objects that fit their goals (e.g. targets presented matching targets that are directed to search for) (Soto, Hodsoll, Rotshtein, and Humhreys, 2008). With that, WM strongly affects visual selection and searching for targets. An example of this is seen when looking for a red target and attention is captured by an unrelated salient stimulus. This is more likely to happen when the irrelevant salient stimuli share similar properties with the target (Folk, Remington, & Johnston, 1992; Bacon & Egeth, 1994; Leber & Egeth, 2006)

Visual object properties compete against each other for attention, then gaining access to awareness and higher-level processing, which results in recall ability (Soto et al., 2008). Mechanisms allowing for an object to gain attention and awareness include bottom-up, stimulus driven influences (salient object properties) and top down sources such as identifying an object that has significance. With WM modulating visual processing, targets are more efficiently detected when they are more salient (the objects features are different from the distractors). Even though the object features drive attention and higher-level processing toward the more salient objects more efficiently, Hodsoll and Humphreys (2005) found that these salient features are only as effective as the participants holding a template of the target features in WM. Categorical differences in objects were found effective when the participants held a correct image of the target features in WM. Soto, Hodsoll, Rotshtein, and Humhreys (2008) additionally reported that the ability to attend to stimuli can be modulated by whether the stimuli match the current contents in WM. The selection process happens automatically, whether it impairs performance or not. The AB is an example of an automatic selection process that impairs performance. Soto, Humphrey's, and Heinke (2006) reported that the contents and expectancies of WM modulate selection of targets even when the target's salience is designed to influence WM.

These findings affirm the importance of object salience as well as introduce the relationship that WM has with salience and the reliance on WM template matching. The connection between the AB and WM consolidation has been established in previous AB literature. The connection between WM consolidation and target salience has additionally been established in literature. The connection between the AB and target salience has not been thoroughly researched and established in previous literature. With the connection of these topics in the AB construct, it is natural to explore the effect that target salience has on the AB. Reviewing findings related to the AB, WM, and salience provide insight into the trends, inconsistencies, and gaps that can be investigated further.

Literature Review

Search Methods

In order to thoroughly search for literature addressing the AB, salience, and timing as an effect on working memory consolidation in the AB, I searched for four different term combinations. I searched the terms: Attentional blink AND salience, attentional blink AND working memory AND salience, attentional blink AND working memory consolidation AND salience, attentional blink AND working memory AND timing. I searched these terms in the databases PubMed, PsycInfo, and PsycArticles. I chose the databases based on my topic being heavily researched in the cognitive psychology field. I did not set a date specification due to the short supply of articles addressing the attentional blink, working memory, salience, and timing. PubMed provided 67 search results. Through my exclusion and inclusion criteria, I selected 11 papers to include. PsycInfo provided 40 search results. Through my exclusion and inclusion criteria, I selected 9 papers to include. 7 papers were excluded due to duplicate results with previously included papers. PsycArticles provided 33 results. A majority of the results included duplicate results. Through my exclusion and inclusion criteria, I selected 0 papers to include. A graphic outlining my inclusion and exclusion decision making process is provided below.

Inclusion/Exclusion Criteria

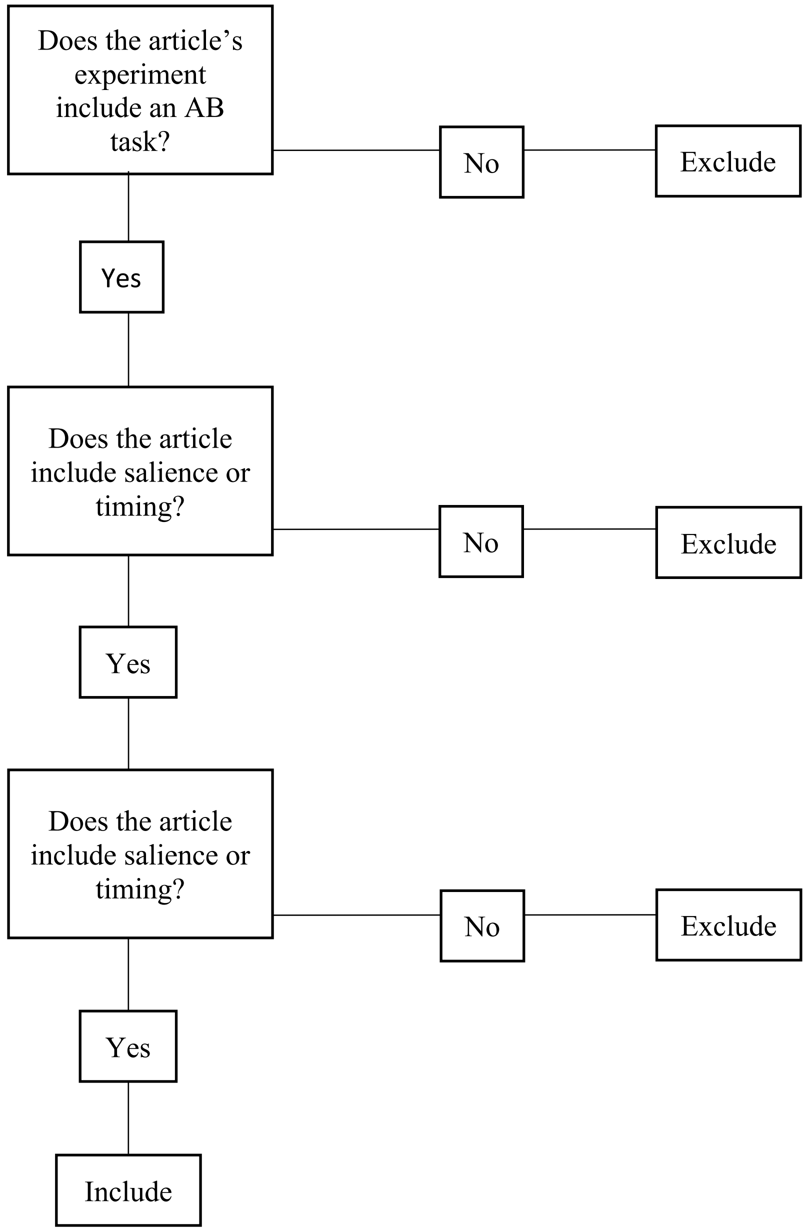

Figure 3. Inclusion and exclusion criteria map.

In total, 20 articles met the inclusion criteria, which are discussed. The table below will present each article that has been included, the AB study design, number of participants, and relevant findings. Following the chart, the included articles are compared, contrasted, and examined for holes that can be filled or researched further.

Analysis

The following articles were found based on the search criteria outlined above.

Study	Study Design	N	Relevant Findings
Raymond, J. E., & Brien, J. L. O. (2009). Selective visual attention and motivation.	Measured recognition of previously seen faces involving wins and losses with and without attentional constraints	24	Motivational Salience did not affect attentional decisions when it was not under limitations; when attention was limited (AB), visual processing favored reward associated objects
Engen, H. G., Smallwood, J., & Singer, T. (2017). Differential impact of emotional task relevance on three indices of prioritised processing for fearful and angry facial expressions.	Participants judged the emotion or gender of faces (angry, neutral, fearful). Attention was measured by the AB deficits	29	Task relevant fearful faces captured and held attention more than neutral. Angry faces captured but did not hold attention more than fearful and neutral. Only fearful task irrelevant faces capture attention
Lagroix, H. E. P., Patten, J. W., Di Lollo, V., & Spalek, T. M. (2016). Perception of temporal order during the attentional blink: Using stimulus salience to modulate prior entry.	Three letters were presented in a stream of digits. T2 and T3 salience was manipulated	57	When multiple targets are presented in the AB, the order of presentation is often confused. Order perception was enhanced when T2 was more salient and impaired when T3 was salient
Cecilia, J., Galceran, J., Salvador, J., Puy, J., & Mas, F. (1994). Numerical procedures in electrochemical simulation.	T1 (A flower) was presented within an RSVP followed by T2 (A face)	12	Found faces and objects are immune to the AB. When T1 was more demanding, there was more of an AB with faces and objects
Robinson, A. K., Mattingley, J. B., & Reinhard, J. (2013). Odors enhance the salience of matching images during the attentional blink.	Participants viewed an RSVP stream of odor related objects. Participants inhaled a congruent	20	Congruent odors reduced the attentional blink in comparison to incongruent and neutral odors. Congruent odors and visuals are more

	odor, incongruent odor or neutral odor		salient, enhancing attention
Keil, A., Ihssen, N., & Heim, S. (2006). Early Cortical Facilitation for Emotionally arousing targets during Attentional Blinks.	T2 was a neutral, pleasant, or unpleasant written word among an RSVP stream of neutral words	13	Reports of pleasant and unpleasant words was more accurate than neutral words. Arousing words are preferable in selecting for attention, leading to preferential processing in working memory and visual awareness
Vogel, E. K., & Luck, S. J. (2002). Delayed working memory consolidation during the attentional blink.	Compared T2 as the last item in the RSVP stream versus items following T2. Measured the P3 wave thought to represent WM consolidation	10	When T2 was followed by a mask, the P3 was suppressed, T2 was not consolidated. When T2 was the last item, P3 was delayed, not suppressed; T2 was delayed in consolidation. Show the limit in the AB is on consolidating in WM.
Keil, A., & Ihssen, N. (2004). Identification Facilitation for Emotionally Arousing Verbs during the Attentional Blink.	Pleasant, neutral and unpleasant verbs were presented as T2 in an RSVP stream	19	Pleasant and unpleasant T2's increased reporting accuracy compared to neutral. Pleasant and unpleasant T2's with low emotional arousal did not show the enhancement. Effectively arousing objects are given preference in WM consolidation and attention
Serences, J. (2010). Processing Channels	T1 was a digit followed by T2, a face. Participants completed un-speeded and speeded response trials.	4	Participants were able to report T2 with an un-speeded response. The AB was present when participants were instructed to give a speeded response for T1. Faces are not immune to interference.

MacLeod, J., Stewart, B. M., Newman, A. J., & Arnell, K. M. (2017). Do emotion-induced blindness and the attentional blink share underlying mechanisms? An event-related potential study of emotionally-arousing words.	An emotion word from one of the categories: sex/taboo, threat, positive, negative, anxiety, and neutral was either T1 or a distractor	31	Enhanced AB with an emotionally arousing target. Taboo/sexual words increased activation, WM processing, and WM consolidation.
Damsma, A., van der Mijn, R., & van Rijn, H. (2018). Neural markers of memory consolidation do not predict temporal estimates of encoded items.	Participants completed a traditional AB task and estimated the lag that T2 appeared after. Thinking that estimated delay should match when WM consolidated is delayed.	45	Estimation of the lag did not match WM consolidation delay. They suggest there is no direct link between WM encoding and lag timing.
Olivers, C. N. L., Spalek, T. M., Kawahara, J., & Di Lollo, V. (2009). The attentional blink: Increasing target salience provides no evidence for resource depletion. A commentary on dux, asplund, and marois (2008).	Three targets (T1-T3) are presented in the AB task. Hypothesize that T3 is reported at the expense of T1.	24	When T1 is more salient the AB for T3 reemerges. They explain the findings by saying that the results are due to the differential salience between T1 and T2.
Dux, P. E., Asplund, C. L., & Marois, R. (2009). Both exogenous and endogenous target salience manipulations support resource depletion accounts of the attentional blink: A reply to olivers, spalek, kawahara, and di lollo (2009).	Reference Olivers et al. (2009) study with T1, T2 and T3 and allocated varying amounts of resources directed toward T1.	48	Manipulating target salience and task relevance affects T3 report-ability. They believe this supports the theory that the reason for the AB is T1 resource depletion.
Landau, A. N., & Bentin, S. (2008). Attentional and perceptual factors affecting the attentional blink for faces and objects.	T1 was a flower and T2 was randomly chosen faces or watch faces. The	12	The salience of the face and available resources determine if there is an AB for the faces.

	distractors were furniture.		
Lagroix, H. E. P., Spalek, T. M., & Di Lollo, V. (2011). The role of observer strategy in the single-target AB paradigm.	One or both T1 and T2 were uppercase letters. T2 followed a pattern mask.	47	Results were inconsistent with the enhanced salience hypothesis that the absence of masking in the last distractor enhances attention and is processed like T1, causing an AB.
Beech, A. R., Kalmus, E., Tipper, S. P., Baudouin, J., Flak, V., & Humphreys, G. W. (2008). Children induce an enhanced attentional blink in child molesters.	T1 was pictures of children in a sample of child molesters to see if a more salient T1 increases the AB.	35	The AB was larger when there was a picture of a child versus a picture of an animal, supporting that a more salient T1 makes the AB larger.
Tibboel, H., De Houwer, J., Van Bockstaele, B., & Verschuere, B. (2013). Is the diminished attentional blink for salient T2 stimuli driven by a response bias?	The AB is expected to diminish when T2 is more salient. T2 was the participants own name or stimuli forming a coherent category.	22	The experiments confirmed that the AB is diminished and theorized that it is due to more efficient processing for a more salient target and not a bias to report a more salient stimulus.
Shih, S., & Reeves, A. (2007). Attentional capture in rapid serial visual presentation.	They adjusted the chromaticity at equiluminance for T1, T2 or a distractor.	18	The extent of the AB varied entirely by the salience of T2, not with T1 salience. A salient distractor before T2 reduced the AB; a salient distractor after T2 did not affect the AB.
Waters, A. J., Heishman, S. J., Lerman, C., & Pickworth, W. (2007). Enhanced identification of smoking-related words during the attentional blink in smokers.	Presented smoking related stimuli to smokers for T2.	55	Smoking related T2 targets were recalled better than neutral T2's at early but not late lags.
De Martino, B., Kalisch, R., Rees, G., & Dolan, R. J. (2009). Enhanced processing of threat	Manipulated the salience of the second (T2) of two face targets.		Fearful faces were identified significantly more than neutral faces.

stimuli under limited attentional resources.			

Table 2. Literature review articles.

A takeaway from the table of studies shows that the difference between salience in T1 and T2 can cause or attenuate the AB. Typically, a more salient T1 causes the AB to occur and a more salient T2 attenuates the AB. Methods for salience previously studied include name, odor, children, faces, three targets, or emotion words. The most studied sources of salience include three targets, emotion words, and emotion faces. Of the twenty studies reported, six studies examined emotion faces, three studies examined emotion words, and three studies examined three targets. Odor and name are the least examined forms of salience. Salience manipulations to letters and digits such as color, movement, size, and character have not been studied in the literature presented on the AB.

The previous studies have used a variety of salient targets for T2 such as faces, facial expressions, or taboo words. While these are effective in testing for salience, we are unable to gauge what degree of salience is affecting the AB (e.g. how salient is a face?). Additionally, confounds may exist with stimuli such as faces, emotion words, and taboo words, that are contributing to the results. A study examining degrees of salience in and between T1 and T2 with the fewest amount of confounds will begin to establish the relationship between the AB and salience.

A way that this can be explored is by varying the salience of T1 and/or T2 in the AB task. Exploring the difference in salience between T1 and T2 will begin to establish the minimum and maximum salience difference that can occur between T1 and T2, to attenuate or cause the AB. I propose the term salience difference, in this case, to represent if salience were quantified mathematically. T2 – T1 = salience difference. A positive solution in the equation means T2 is more salient and is expected to attenuate the AB. A negative solution in the equation represents a more salient T1, resulting in an AB. An example of varying salience difference is varying the stimuli type (number versus letter), color (white versus red), size (big versus small), or movement (stagnant versus looming). These examples can be applied in examining the salience difference between targets, the impact salience has on the AB, and the salience difference threshold that contributes to and attenuates the AB. The set of studies presented examined the effect that salience has on the AB, specifically, exploring the effects of T1 and T2 salience on the AB.

Experiment 1: Target Size

Experiment one examined two experimental conditions: condition one, where T1 was more salient than T2 and condition two, where T2 was more salient than T1. In this study, target size was the salience manipulation. Accuracy of reporting T2 was the dependent variable. Accuracy of reporting T2 was dependent on which target was more salient (T1 or T2) and degree of salience. The degree of salience varied in each condition. In example, in condition one, T2 remained the default (32 point) size. T1 was presented randomly at one of the size manipulations: 150% of its default size: 48 point, and 200% of its default size: 64 point. The same is true for condition two, where T2 was more salient. An additional variable that examined was T2 lag positioning, a customary variable in AB research. Accuracy of reporting T2 was assessed while T2 was presented randomly at lags one through eight. This allowed assessment of how salience affects T2 reporting accuracy at each lag.

I explored three research questions:

1. Does target salience (control versus condition 1 versus condition 2) affect accuracy of reporting T2 (i.e. How are AB results affected when T1 is more salient or T2 is more salient, compared to the control)?
2. How does target salience (condition 1 versus condition 2) affect accuracy for reporting T2 at each lag (lag 1-8)? This question will explore any changes in the AB pattern within each condition.
3. Does degree of salience (150% versus 200%) within each condition affect accuracy for reporting T2 (i.e. Are AB results affected as the targets become more salient)?

Additionally, I developed hypotheses in coordination with my research questions:

1. Target salience will affect accuracy for reporting T2. Specifically, condition 2 (where T2 is more salient) will result in increased accuracy of reporting T2, compared to condition 1 (where T1 is more salient). This represents resistance to the AB. Additionally, condition one will continue to show an AB effect.
2. Accuracy for reporting T2 at each lag will remain consistent with the idealized attentional blink results, shown in figure two, in both conditions. This means that the shape of the results when charted will remain; although, the proportion of correctly reported T2's (shown on the y-axis in figure 2), will differ between each condition, representing my first hypothesis. The same AB shape will hold but be shifted upward, representing increased accuracy of reporting.
3. There will be a significant difference between salience sizes (150% versus 200% of the original size) within each condition. In condition one (where T1 is more salient), accuracy for reporting T2 will decrease as the T1 degree of salience

increases: a negative correlation. In condition two (where T2 is more salient), accuracy for reporting T2 will increase as the T2 degree of salience increases: a positive correlation.

Methods

Participants.

25 Arizona State University undergraduate students participated in the study. Students were recruited from an Engineering Statistics (EGR 280) course. The course consisted of 70 undergraduate students enrolled in an engineering program of study. Participants received extra class credit for participating in the study. The sample size was determined using G Power software, with the significance level set at alpha equaling .05. There was one prerequisite for participating in my study, where students must have normal or corrected normal vision. Features that set participants in the recruitment pool apart from the general population include expected education level, age, and socioeconomic status. The features listed are expected to differ from the general population due the environment that they are recruited from. These features will be mentioned in the limitations section, addressing generalizability.

Materials.

Materials used include computers, keyboards, and desks. I used computers to display the task, prompting response on the connected keyboard. Participants sat at a desk in a designated laboratory room, free of distractions. The program, Open Sesame, was used to run the task, collect keyboard responses, and generate the data file.

Design.

This study was a repeated measures design where each subject participated in all conditions. There was one control condition and two experimental conditions, each with two within condition variables. The two conditions are unique in which target is presented as more salient. In condition one, T1 is more salient (150% and 200% of the default size), while T2 always remains the default size. In condition two, T2 is more salient (150% and 200% of the default size) while T1 remains the default size. Salience values (size differences) were based on Mounts and Gavett’s (2004) study. They ran a variation of an AB task, examining the effects of differing target sizes within a visual search task. They found a significant main effect when the more salient stimulus was 200% of the default size (9-point to 18-point size). Mounts and Gavett’s (2004) finding established that there is a detectable difference when target size is 200% of the original (double in size). The Mounts and Gavett (2004) study informed decisions regarding stimulus sizes. The target sizes and pairings for trials are depicted in table 1.

X% = X% of original target size 120 total trials		**Target 2**		
		100% (32 point)	**150%** (48 point)	**200%** (64 point)
Target 1	**100%** (32 point)	Control 3 trials at each lag 1-8 24 trials	T2 + 50% 3 trials at each lag 1-8 24 trials	T2 + 100% 3 trials at each lag 1-8 24 trials
	150% (48 point)	T1 + 50% 3 trials at each lag 1-8 24 trials	X (Will not run)	X (Will not run)
	200% (64 point)	T1 + 100% 3 trials at each lag 1-8 24 trials	X (Will not run)	X (Will not run)

Table 3. Experiment 1 conditions and trial numbers.

Table one shows exploratory percentages and can be set at smaller intervals in future studies to determine more precise detectable differences. An example of a trial, where T2 is 150% larger than T1 is simplified and represented in figure 4.

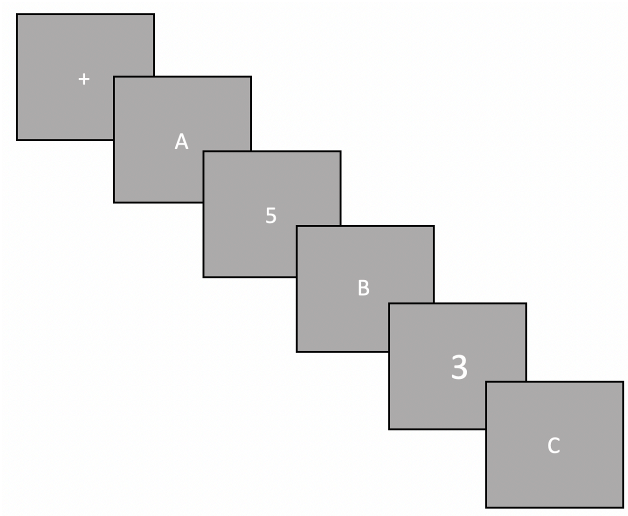

Figure 4. Simplified version of one trial in condition two, 150% larger condition.

In this study, the independent variables are target salience, degree of salience, and lag positioning. The dependent variable is accuracy of reporting T2. An extraneous variable is accuracy of reporting T1. Only trials where T1 was reported correctly were analyzed, to ensure T1 was sufficiently attended to.

Procedures.

The specific procedures such as presentation rate, letter size and procedure setup are based on the AB study run by Raymond, Shapiro, and Arnell (1992). A stream of black letters (distractors) were presented with two black numbers (targets) presented within the stream of letters. Stimuli were displayed at the center of a gray colored background. Stimuli were size 32-point font. Each stimulus was presented for 15 milliseconds with inter-stimulus intervals at 75 milliseconds. The presentation rate equaled 11.11 letters per second. T1 appeared in any one of the positions 7 through 15 from the first letter in each trial. The number of stimuli succeeding T1 were always eight. T2 appeared randomly in any of the eight positions on each trial (lag 1-8). After instructions, participants began trials by pressing the spacebar. The trials began with a small black fixation cross, lasting 180 milliseconds. Participants completed ten practice trials, which were repeated if necessary. Following practice trials, they completed 24 trials in each condition, 120 trials in total. All trials were randomized. The breakdown of these trials is shown in table one. Task instructions directed participants to report each number that appeared (T1 and T2) in the stream.

Results

Data were cleaned by adjusting accuracy to include any targets that were reported correctly in either target position one or two (e.g. if the participant reported the T1 stimulus as the second number, they received credit for reporting T1 correctly). This was done for T2 in the same way. With that, trials were only analyzed when T1 was reported correctly. This is to ensure that participants attended to T1 fully. Additionally, trials where the respondent took above three standard deviations of the mean reaction time to respond were filtered out.

A two-way repeated measures ANOVA was run to compare the interactions and main effects of conditions and lags on the accuracy of reporting T2. Condition type included three levels (control, condition one, and condition two) and lags contained eight levels (lags one through eight). There was not a significant interaction effect between conditions and lags on the accuracy of reporting T2, $F(7, 164) = 1.83$, $p > .05$.

Both main effects were statistically significant at the .05 level. The lags main effect met all assumptions except for the test of sphericity. Because of this, I used the

Greenhouse-Geisser test. The main effect for lags yielded an F ratio of (5, 105) = 21.5, $p < .001$, indicating a significant difference between lags one ($M = .82$, $SD = .23$), two ($M = .65$, $SD = .29$), three ($M = .61$, $SD = .33$), four ($M = .68$, $SD = .29$), five ($M = .80$, $SD = .26$), six ($M = .88$, $SD = .19$), seven ($M = .90$, $SD = .19$), and eight ($M = .94$, $SD = .13$). Post hoc multiple comparisons through the Bonferroni method showed that lags two, three and four had no significant differences between them and lags 1, 5, 6, 7, and 8 had no significant differences between them (except between lags 1 and 8 and lags 5 and 8). Lag 2, 3, and 4 were significantly different from lags 1, 5, 6, 7, and 8 (except lags 4 and 5). This is shown in figure 5 where lags 1, 5, 6, 7, and 8 have a mean value of $M = .87$ and lags 2, 3, and 4 have a mean value of $M = .63$.

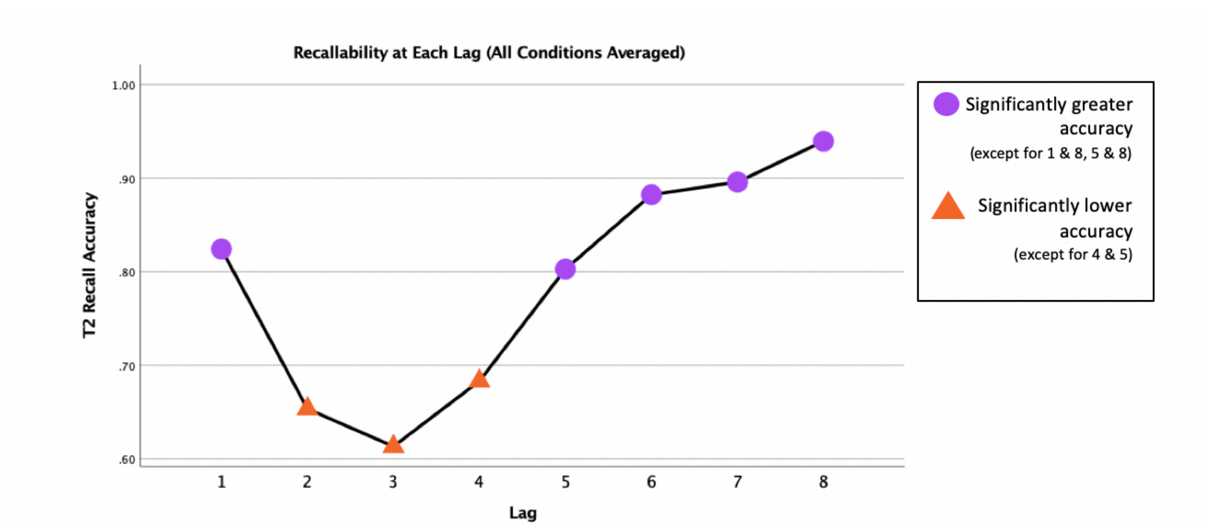

Figure 5. Attentional blink salience overall lag results.

The main effect for conditions (control, condition one, and condition two) met all assumptions and yielded an F ratio of $F(2, 46) = 84.9$, $p < .001$, indicating that the effect of condition type was significant, control ($M = .74$, $SD = .11$), condition one (T1 larger) ($M = .70$, $SD = .11$), condition two (T2 larger) ($M = .92$, $SD = .08$). As a note, the main effect for condition averages the accuracy across all lags for each condition. This main effect tells us that there is a statistical difference in the average accuracy across all lags between conditions. This does not tell us if the accuracy is statistically different between conditions at specific lags. Simple main effects tests will tell us how the conditions differ at each lag, showing how condition affects the AB. Post hoc multiple comparisons through the Bonferroni method showed significant differences between condition two and the control ($p < .001$) as well as condition two and condition one ($p < .001$). There was not a significant difference between condition one and the control.

A simple main effects analysis showed, in the control condition, lag two was approaching significance when compared to lag seven and eight. Lag three was significantly different from lag eight, and lag four was significantly different from lag seven and eight (p values shown in table 4). Figure 6 visualizes the control condition results.

Condition	**Lags**	**P-Value**
Control	Lag 2 and 7	.057
Control	Lag 2 and 8	.060
Control	Lag 3 and 8	.003
Control	Lag 4 and 7	.041
Control	Lag 4 and 8	.007
Condition 1	Lag 1 and 2	.004
Condition 1	Lag 1 and 3	.047
Condition 1	Lag 1 and 8	.024
Condition 1	Lag 2 and 5	.038
Condition 1	Lag 2 and 6	< .001
Condition 1	Lag 2 and 7	< .001
Condition 1	Lag 2 and 8	< .001
Condition1	Lag 3 and 5	.002
Condition 1	Lag 3 and 6	< .001
Condition 1	Lag 3 and 7	< .001
Condition 1	Lag 3 and 8	< .001
Condition 1	Lag 4 and 6	.009

Condition 1	Lag 4 and 7	.013
Condition 1	Lag 4 and 8	<.001
Condition 1	Lag 5 and 8	.008
Condition 2	Lag 1 and 2	.008
Condition 2	Lag 2 and 5	.024
Condition 2	Lag 2 and 7	.038
Condition 2	Lag 2 and 8	.012
Condition 2	Lag 3 and 6	.042
Condition 2	Lag 3 and 7	.016
Condition 2	Lag 3 and 8	.016

Table 4. Significantly different lags in each size condition.

In condition one, where T1 is larger, lag one was significantly different from lags two, three, and eight. Lags two and three were significantly different from lags five, six, seven, and eight (refer to table 4 for p-values). Lag four was significantly different from lags six, seven, and eight. Lag five was significantly different from lag eight. Figure 6 visualizes the condition one results.

In condition two, where T2 is larger, lag one was significantly different from lag two. Lag two was significantly different from lags five, seven and eight, and lag three was significantly different from lags six, seven, and eight (Refer to table four for p-values). Figure 6 visualizes condition two results.

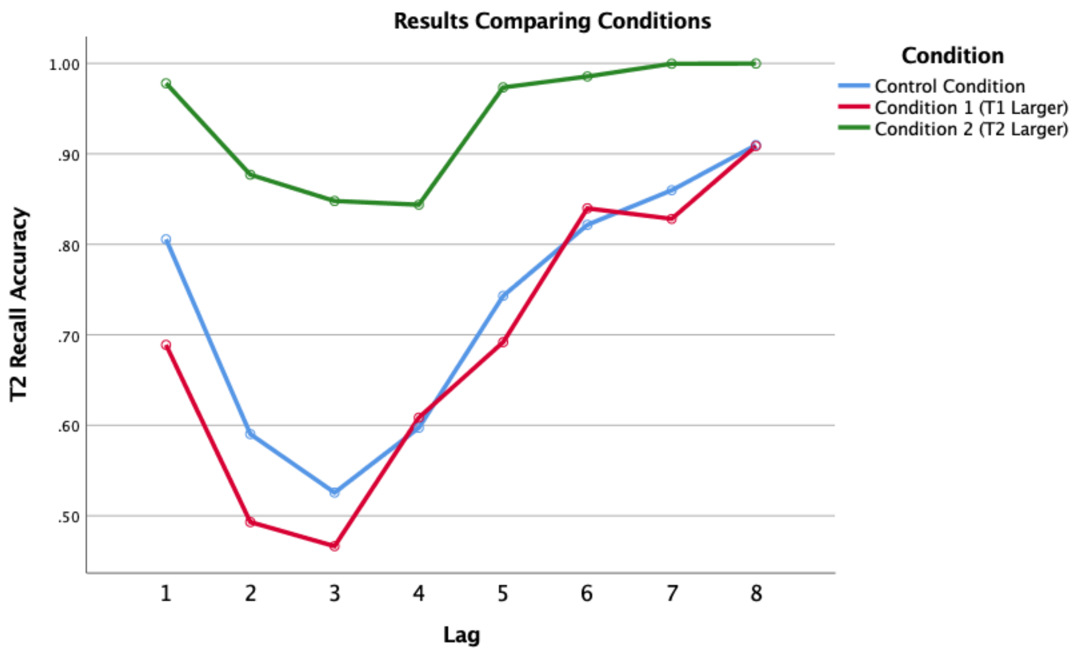

Figure 6. Attentional blink size condition results.

To assess whether there were differences in accuracy between size manipulations within condition one and two (150% versus 200% size difference), a one-way repeated measures ANOVA was run to compare condition size on accuracy of reporting T2. Condition size included four levels, including condition one: T1 at 150% larger and T1 at 200% larger and condition two: T2 at 150% larger and T2 at 200% larger. The main effect for size yielded an F ratio of $F(2, 52) = 44.47$, $p < .001$. Post hoc multiple comparisons through the Bonferroni method showed that condition one at 150% and 200% of the original size were reported with about equal probability ($M = .70$). Condition two at 150% and 200% were also reported with approximately equal probability ($M = .91$). There was a significant difference between condition one and condition two overall ($p < .001$). Figure 7 shows a visual representation of each of the size manipulations within condition one and two.

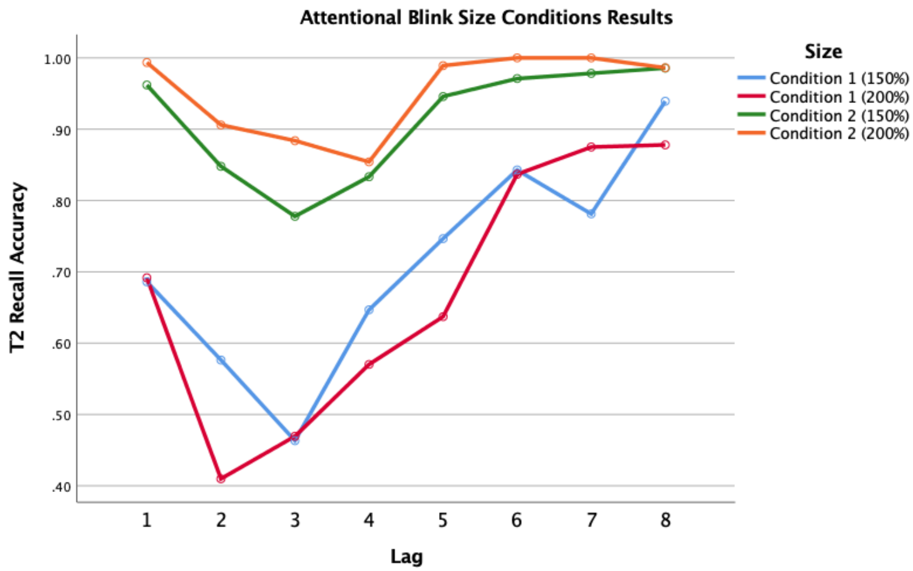

Figure 7. Attentional blink condition size results.

The previous findings lead to questioning whether the larger T2, leading to a reduced attentional blink reduces accuracy of reporting T1. To test this, a one-way repeated measures ANOVA was run, comparing average accuracy of reporting T1 in the control condition (M = .86, SD = .12), condition one (M = .98, SD = .03), and condition two (M = .84, SD = .10). The ANOVA resulted in an overall significant difference among the three conditions $F(2, 48) = 29.13$, $p < .001$. A Bonferroni post hoc test revealed that when T2 is larger (condition two), it does not reduce accuracy of recalling T1 when compared to the control condition. This suggests that a larger T2 increases accuracy of reporting T2 while it does not decrease recall of T1. When T1 is larger, accuracy of recalling T1 is significantly greater than the control $p < .001$. Additionally, when T1 is larger (condition one), accuracy of recalling T1 is significantly greater than condition two (T2 larger) $p < .001$.

Discussion

The results, revealing a significant difference in accuracy between condition two and condition one as well as a significant difference between condition two and the control condition suggest that more salience in T2, when compared to T1 most effects the AB results. The lack of significance between the control condition and condition one suggests that changing the size of T1 has less of an effect on the AB results. The results confirmed previously mentioned hypotheses that condition two (larger T2) significantly improved overall accuracy. With that, condition one (larger T1) decreased accuracy (not significant) when compared to the control.

In regard to research question two, the results revealed that an AB effect still exists in condition one, where T1 is larger. Conversely, in condition two, the AB effect is diminished. This supports the notion that manipulating the salience of T2 is an effective approach to alleviating the AB.

Results showing when the AB is attenuated through a larger T2, reporting T1 is not significantly affected. This suggests that attentional resources that are applied to T2 due to salience do not reduce attentional resources applied to this suggests salience in the form of size supported increased recall for T2 and sustained recall at T1.

Finally, results revealed that there was not a significant difference between sizes within each condition (150% versus 200% size increase). This finding begins to establish the threshold for detectable differences in salience of size and shows that future testing is needed to examine smaller size differences to establish detectable differences in reportability.

Limitations

There are limitations to my study that can be solved with future research and avoiding overgeneralizations. As mentioned previously, the subject pool, based on recruitment from a university, may have limitations in age, socioeconomic status, and education level. To reiterate, results reporting, and inferences should avoid over generalizing. This study examines one type of salience among many possible variations (e.g. color, brightness, color, and movement). Future studies should examine other types of salience to test if the results remain consistent. An additional limitation is the limited range of degrees of salience. This study examined target size at 100%, 150%, and 200% salience. More intervals in target size will further explore the relationship between salience and the AB. Finally, this study examined the AB on a computer task. This topic should also be examined in its presence in real-world scenarios. The limitations support the need to continue to analyze the AB in varying scenarios with different sources of salience.

Experiment 2: Dynamic Stimuli

The previous study showed that increased size salience in T2 altered AB results while size salience in T1 did not. The next set of studies set out to examine whether another (more salient) form of stimuli as T1 will yield altered AB results. Study two examined dynamic stimuli as T1 and how it affects the AB. This explored moving stimulus, which elicits an evolutionary response in attention affects the AB. Movement has been shown to be a salient feature, attracting attention more than stagnant stimuli. Dynamic stimuli as T1 explores how induced attention from movement affects attention allocation and recall for stimuli following movement. Dynamic through looming and receding targets, has been shown to affect attentional allocation through looming and receding targets (Franceroni and Simons, 2003).

Looming stimuli appear to be moving toward the viewer. Examples of a looming object include an oncoming collision, or a ball being thrown to the viewer (Franceroni and Simons 2003). They found that looming objects to strongly capture attention, even more so than abrupt appearances of stimuli. They determined this may represent the need for looming objects to require immediate action. Looming objects are determined to be behaviorally urgent, whereas receding objects are not determined to be urgent, but do capture attention.

Receding objects appear to be moving away from the viewer. An example of this is a ball being thrown away from the viewer. Franceroni and Simons (2003) found receding objects to capture significantly less attention. They hypothesize this is due to the absence of a need for immediate action. Examining these findings in the attentional blink allow us to test the effect that stimulus attentional relevancy has on attending to T1 as well as accuracy of reporting T2 following dynamic stimuli.

The research question in this experiment asked whether dynamic stimuli as T1 would affect the participants ability to recall T2. Specifically, how does a looming T1 affect recall for T2? And how does a receding T1 affect recall for T2? I hypothesized that a looming T1 stimuli will be more salient, resulting in better recall of T2 at all lags, compared to the control, while a receding stimulus will not induce urgency, failing to increase accuracy of reporting T2. In total, I explored the effects that dynamic stimuli (T1) have on the accuracy of recall for subsequent targets (T2).

Experiment 2a

Methods

Participants.

68 Arizona State University undergraduate students voluntarily participated. Students were recruited from the Arizona State University, Tempe campus SONA subject pool. The subject pool consisted of students enrolled in Psychology 101 courses. Participants received SONA credit for participating. The sample size was determined using G power software with a significance level set at .05. Participants were required to have normal or corrected normal vision.

Materials.

Materials used include computers, keyboards, and desks. I used computers to display the task, prompting response on the connected keyboard. Participants sat at a desk in a designated laboratory room, free of distractions. I used the software, Media Lab, to run the study. The program was used to run the task, collect keyboard responses, and generate the data file.

Design.

This study is a repeated measures design where each subject participated in all conditions. The task included experimental trials where either T1, T2, or distractors were presented as dynamic. Trials where T2 or the distractors were dynamic were determined unusable due to error in the task programming. For the purposes of this study only trials where T1 was dynamic were analyzed. There was one control condition and two experimental conditions. The two experimental conditions were the looming and receding conditions.

The control condition presented both targets with no movement. The looming condition presented the stimuli at the default 16-point size to begin and progressively grew larger, ending at 100% larger than the default. The receding condition presented the stimuli at the same size 16-point font and progressively became smaller to 100% of its original size. Participants received eight trials at each lag (four lags) within each condition (control, looming, receding). Participants completed 224 trials total with 96 trials analyzed (T1 dynamic).

Procedures.

Participants pressed the spacebar to begin each trial. A fixation dot appeared for 180 milliseconds, indicating the beginning of the trial. Participants were instructed to report the first number they saw by responding with the number pad on a keyboard. They were instructed to respond with 0 if they did not know which number they saw. Next, they were instructed to report the second number (T2). They were instructed to respond with zero if they did not see T2.

A stream of red letters (distractors) were presented with two red numbers (targets) presented within the stream of letters. Stimuli were displayed at 16-point font on a black background. Each stimulus was presented for 15 milliseconds with 75 milliseconds inter stimulus intervals. The presentation rate results in 11.11 letters per second. T1 was randomly presented in position seven through fifteen from the start of the RSVP. T2 appeared randomly at lag one through four after T1. Participants completed 20 practice trials. All trials were randomized.

Results

A two-way repeated measures ANOVA was run to compare the interactions and main effects of conditions and lags on the accuracy of reporting T2. Condition type included three levels (control, looming, and receding) and lags contained four levels (lag one, two, three, and four). There was a significant interaction effect between conditions and lags on the accuracy of reporting T2, $F(6, 168) = 3.93$, $p = .001$.

Both main effects were statistically significant at the .05 level except for the conditions factor. The main effect, lags, met all assumptions except for the test of sphericity. Because of this, I used the Greenhouse-Geisser main effects test. The main effect for lags yielded an F ratio of $(2, 64) = 12.23$, $p < .001$, indicating a significant difference between lags one ($M = .81$, $SD = .33$), two ($M = .50$, $SD = .35$), three ($M = .55$, $SD = .36$), and four ($M = .54$, $SD = .33$). Post hoc multiple comparisons through the Bonferroni method show that lag one had significantly more accuracy than lags two, three, and four ($p < .001$). There was not a significant difference between lag two, three, and four.

The main effect for conditions (control, looming, receding) met all assumptions and yielded an F ratio of $F(2, 56) = 1.93$, $p > .05$, indicating that the effect of condition was not significant, looming ($M = .67$, $SD = .31$), control ($M = .74$, $SD = .25$), receding ($M = .71$, $SD = .30$). Of note, the main effect for condition averages the accuracy across all lags for each condition. This main effect tells us that there is not a statistical difference in the average accuracy across all lags. This does not tell us if the accuracy is statistically different between conditions at specific lags.

A simple main effects analysis showed that T2 recall in the receding condition was significantly higher than the control condition at lag two ($p = .042$). The looming condition was significantly lower than the control condition at lag three ($p = .001$). The looming and receding conditions did not have any significant differences at any lag positions in the Bonferroni posttest. To further explore the difference between the looming and receding conditions at lag two (where the AB is highest), a paired samples t-test at lag two revealed there was not a significant difference between the looming ($M = .67$, $SD = .38$) and receding ($M = .72$, $SD = .27$) conditions $t(65) = .461$, $p > .05$. Figure 7 shows a visual representation of the conditions at each lag.

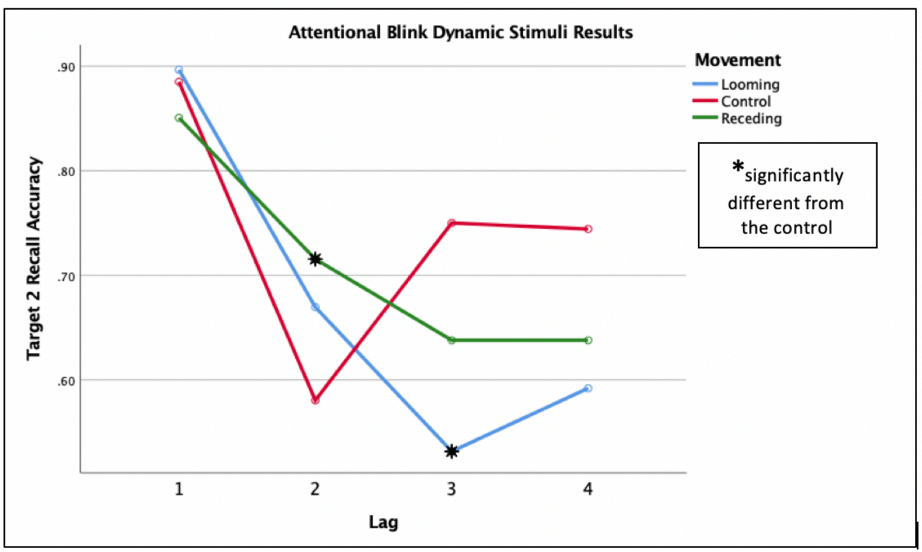

Figure 8. Attentional blink dynamic stimuli results (16-point font).

Experiment 2b

In an additional study, I examined the effects of dynamic stimuli on the AB with a larger font size than experiment 2a. Looming and receding conditions presented as larger, typically represents objects being closer; therefore, increasing urgency of responding and attending to the stimuli. With this experiment, I hypothesized that looming and receding stimuli would have an effect on the AB, due to the appearance of the stimuli being larger and simulating an object closer to the participant.

Methods

Participants.

68 Arizona State University undergraduate students voluntarily participated. Students were recruited from the ASU Tempe SONA subject pool. The subject pool consisted of students enrolled in Psychology 101 courses. Participants received SONA credit for participating. The sample size was determined using G power software with a significance level set at .05. Participants were required to have normal or corrected normal vision.

Materials.

Materials used include computers, keyboards, and desks. I used computers to display the task, prompting response on the connected keyboard. Participants sat at a desk in a designated laboratory room, free of distractions. I used the software, Media Lab, to run the study. The program was used to run the task, collect keyboard responses, and generate the data file.

Design.

This study is a repeated measures design where each subject participated in all conditions. The task included experimental trials where either T1, T2, or distractors were presented as dynamic. Trials where T2 or the distractors were dynamic were determined unusable due to error in the task programming. For the purposes of this study only trials where T1 was dynamic were analyzed. There was one control condition and two experimental conditions. The two experimental conditions were the looming and receding conditions.

The control condition presented both targets with no movement. The looming condition presented the stimuli at the default 32-point size to begin and progressively grew larger, ending at 100% larger than the default. The receding condition presented the stimuli at the same size 32-point font and progressively became smaller to 100% of its original size. Participants received eight trials at each lag (four lags) within each condition (control, looming, receding). Participants completed 224 trials total with 96 trials analyzed (T1 dynamic).

Procedures.

Participants pressed the spacebar to begin each trial. A fixation dot appeared for 180 milliseconds, indicating the beginning of the trial. Participants were instructed to report the first number they saw by responding with the number pad on a keyboard. They were instructed to respond with 0 if they did not know which number they saw. Next, they were instructed to report the second number (T2). They were instructed to respond with zero if they did not see T2.

A stream of red letters (distractors) were presented with two red numbers (targets) presented within the stream of letters. Stimuli were displayed at 32-point font on a black background. Each stimulus was presented for 15 milliseconds with 75 milliseconds inter stimulus intervals. The presentation rate results in 11.11 letters per second. T1 was randomly presented in position seven through fifteen from the start of the RSVP. T2 appeared randomly at lag one through four after T1. Participants completed 20 practice trials. All trials were randomized.

Results

A two-way repeated measures ANOVA was run to compare the interaction and main effects of conditions and lags on the accuracy of reporting T2. Condition type included three levels (control, looming, and receding) and lags contained four levels (lag one, two, three, and four). There was a significant interaction effect between conditions and lags on the accuracy of reporting T2, $F(6, 44) = 5.57$, $p <.001$.

Both main effects were statistically significant at the .05 level except for the condition factor. The lags condition met all assumptions except for the test of sphericity. Because of this, I used the Greenhouse-Geisser test main effects. The main effect for lags yielded an F ratio of $(3, 44) = 29.4$, $p < .001$, indicating a significant difference between lags one ($M = .87$, $SD = .30$), two ($M = .63$, $SD = .33$), three ($M = .61$, $SD = .35$), and four ($M = .62$, $SD = .34$). Post hoc multiple comparisons through the Bonferroni method show that lag one had significantly more accuracy than lag two, three, and four ($p < .001$). There was not a significant difference between lag two, three, and four.

The main effect for conditions (control, looming, receding) met all assumptions and yielded an F ratio of $F(2, 44) = 0.31$, $p > .05$, indicating that the effect of condition type was not significant: looming ($M = .67$, $SD = .32$), control ($M = .68$, $SD = .32$), receding ($M = .69$, $SD = .33$). Of note, the main effect for condition averages the accuracy across all lags for each condition. This main effect tells us that there is not a statistical difference in the average accuracy across all lags. This does not tell us if the accuracy is statistically different between conditions at specific lags, which will tell us how each condition affects AB results.

Simple main effects analysis showed that the looming and receding conditions were significantly higher than the control condition at lag two (looming: $p = .001$, receding: $p = .049$). The looming condition was significantly lower than the control condition at lag three ($p = .046$). The looming condition was significantly lower than the control at lag four (looming: $p < .001$). The receding condition was approaching significance, with lower accuracy than the control at lag four (receding $p = 0.060$). The looming and receding conditions did not have any significant differences at any lag positions in the Bonferroni posttest. To further explore the difference between the looming and receding conditions, I ran a paired t-test at lags two (where the AB is at its highest). A paired samples t-test between the looming and receding conditions at lag two revealed a significant difference between the looming ($M = .69$, $SD = .31$) and receding ($M = .60$, $SD = .35$) conditions $t(68) = 2.34$, $p = .02$. Figure 7 shows a visual representation of the conditions at each lag.

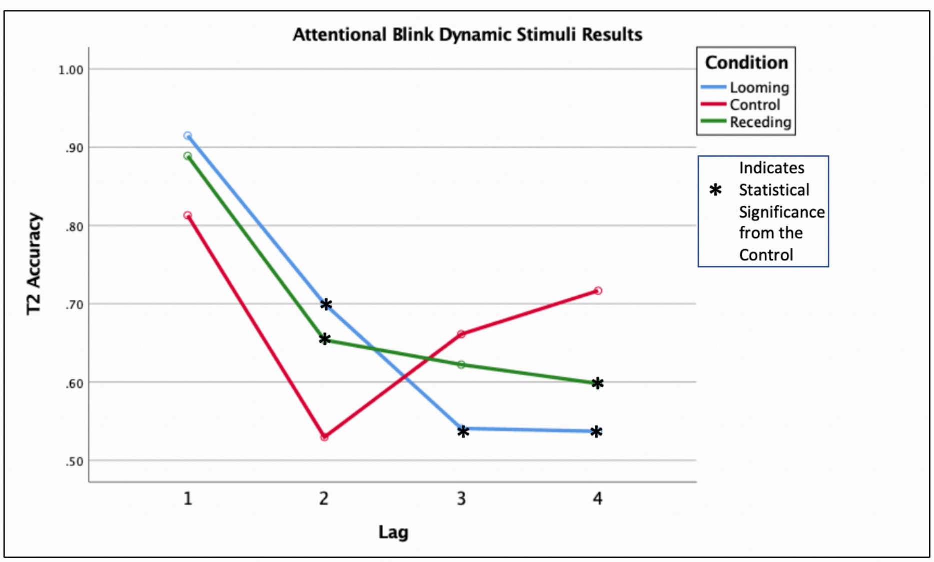

Figure 9. Attentional blink dynamic stimuli results (32-point font).

Discussion

Results indicate that a dynamic T1 increases attention, confirming Franceroni and Simons' (2003) finding that dynamic stimuli capture attention, with looming stimuli captivating attention greater than receding stimuli. In relation to the attentional blink, the looming and receding conditions increased captivation, theoretically opening the attentional gate longer and wider. The data support the notion that more captivating stimuli, cause an immediate boost in attention and recall, at the expense of attentional resources used on later lags. The data show that at lags three and four, participants were significantly worse at attending to and recalling T2. To summarize, the looming and receding T1 captivated attention more than non-moving targets, which caused an increase in recallability at lag two when compared to the control, while it resulted in a period of worse recallability directly following, at lags three and four.

Lag one and two.

Data shows, looming and receding T1 movement facilitates higher detection for T2 at lag two, when compared to the control. This can be compared to a prolonged lag-1 sparing, where the salient T1 temporarily enhanced attention for the following targets. Of note, the traditional lag-1 sparing effect was still present in all conditions.

Williams et al. (2008) believed that lag-1 sparing was due to an attentional gate opened by T1, where resources are still activated when T2 appears immediately following T1. This would suggest that the dynamic T1 increased resources allocated to T1, which then increased resources allocated to T2 (when it immediately followed T1), resulting in greater recall of T2.

The significant increase in recallability at lag two suggests that a more salient T1 in the form of looming and receding movement, requiring more attentional resources, prolongs the amount of time that the theoretical attentional gate is open. The prolonged attentional gate increases recall at lag two when compared to the control. This finding comes at an attentional cost, resulting in a decreased recall at lags three and four.

Lag three and four.

Looming stimuli makes detection of T2 worse at lag three and four, while receding stimuli approached significance for worse recall at lag four. In the typical AB results, attention has time to recover, allowing recall for T2 to gradually increase after lag two. These results suggest that looming stimuli is infringing on the ability of attention to recover in the time period.

Olivers (2007) reported the adaptive functionality associated with lag-1 sparing and the AB. The selection mechanism responds to relevant stimuli and suppresses irrelevant information, better preparing humans for life. Rather than viewing the AB as a reduction in attention after an important event (T1), Nakayama and Mackeben (1989) and Reeves and Sperling (1986) research support that performance is temporarily enhanced (lag-1 sparing) after viewing something that is relevant. Our data indicate that this temporary enhancement leads to a slower recovery time in attention. The findings propose that a deficit in attentional resources occurring later in the task is a direct result of increased attention in the early lags. This finding leaves room for future research questions, hypotheses, and studies.

Limitations and Future Directions.

The studies reviewed results of T2 recallability with four lags. This design allowed fort examining lag one sparing, beginning and end, as well as where the AB occurred. A future study should examine the same variables with eight lags to asses where the attentional blink recovers to a reportable level and where the theoretical attentional gate resets. This would allow for viewing a more robust image of the AB and its relationship to dynamic stimuli related to attentional recovery.

Overall Discussion

Experiment one revealed that the salience difference between T1 and T2 does have an effect on the AB. When T1 was more salient than T2, accuracy of reporting T2 was decreased, although, not significant, when compared to the control. This may be due to the fact that the first target is processed the same when it is presented as larger or the same size as distractors. Future manipulations that require more cognitive attention may show different effects.

T2 reporting accuracy is significantly improved, when compared to the control, when T2 is more salient. This shows that increased salience in the form of a size increase helps mitigate the disadvantage that T2 consolidation is faced due to its appearance while participants are busy consolidating T1. To further support the utility of increasing size salience in T2, the increase in T2 recall does not come at the expense of T1 recall. This suggests that an increased T2 size may alter T1 consolidation, allowing T2 to enter the consolidation period. It is unclear whether chunking or other strategies are used to consolidate both targets. Future research can address this.

Finally, the results reveal that a 50% increase in size salience does not result in significant differences. This suggests that future research is needed to determine the threshold for size differences to affect the AB results. Additionally, the results reveal that care is needed when presenting stimuli to individuals within a 700-millisecond period. When stimuli are competing for attention allocation, working memory consolidation prioritizes the first stimuli. Size manipulations to salience at a 150% size difference in the second target puts more priority on the second stimuli, while not compromising the first stimuli. This information is useful in design decisions, which can establish priority of information through salience manipulations.

The second study examined another type of salience manipulation through movement which revealed that looming and receding information resulted in significant differences in recallability. The studies found that a more salient T1 in the form of dynamic stimuli caused an increase in attention for earlier lags, resulting in better recall and a reduced AB effect. This finding also resulted in significantly worse recall at lags three and four, suggesting that the increase in attention at earlier lags negatively affected attention at later lags. Additionally, the looming condition resulted in more significant differences from the control condition when compared to the receding condition and more extreme results consistent with the patterns seen in both looming and receding conditions. This suggests that the looming condition may cause a larger boost in attention than the receding condition. Although, the two conditions were not significantly different from each other at any lags in the repeated measures ANOVA, showing future, more targeted research may be needed.

Future Studies

Future studies should examine the AB and degree of salience with varying types of target salience. Examples can include size, movement, or color. Additionally, future studies should examine more degrees of salience applied to targets. This will allow for researchers to examine exact differences in salience and establish thresholds for salience affecting the AB. Future studies should also examine the effects that salience may have on the accuracy of reporting T1. My series of studies supports the idea that T2 salience does not affect accuracy of reporting T1, while increasing accuracy of reporting T2. More studies examining looming and receding conditions in the AB are needed. A study examining looming and receding with eight lags will answer questions relating to the AB recovery period. Additionally, other looming and receding presentation types can further explore the conditions. In example, a virtual or augments reality environment can introduce more realistic looming and receding stimuli. Finally, using a general population will benefit generalizability as well as examining the AB in real world scenarios.

Conclusion

This paper examined the previous literature relating to the AB, which found that salience plays a role in the AB results. Previous research has examined salience in environments including faces, taboo words, and participants' names. The literature revealed gaps in examining salience with stimuli that do not act as confounds. In this series of studies, salience was examined in its relation to the AB. The first set of studies showed that when T2 is more salient (larger in size), the AB is attenuated, where when T1 is more salient (larger in size), the AB does not significantly differ from the control. Additionally, when the AB is attenuated by a more salient T2, the accuracy of recalling

T1 is not reduced, suggesting an increase in overall capacity to recall targets. The second set of studies examined salience in T1, exploring whether dynamic stimuli have an effect on AB results. The results showed that dynamic stimuli affect the AB results, where at earlier lags (lag 2), participants, have significantly better recall, and at later lags (lags 3 and 4) participants have significantly worse recall than the control. This suggests that the dynamic stimuli draw attention more than stagnant stimuli and increase attention allocated to T2 at lag 2. The results also showed that this increase in attention caused a decrease in attention directly following lag two. Additionally, this set of studies found that the effect that dynamic T1 stimuli has on the AB is larger when the font is larger. This may suggest that dynamic stimuli affect attention and the AB more when the stimuli require more eminent attention (moving objects that are closer require more attention than further objects). Finally, a paired t-test at lag two (where the AB is highest) show a significant difference between looming and receding, where looming results in greater recall of T2. This is suspected to be due to a greater need for attention when an object is moving toward you rather than away. Overall, the study found that salience in the form of a larger size affects the AB when T2 is larger (attenuating the AB) while it has no effect when T1 is larger. Additional studies found that dynamic T1 stimuli increase attention directly after the dynamic stimuli (lag one and two) and negatively affect attention for the following lags (three and four), by decreasing recall of T2.

REFERENCES

Aston-Jones, G., Rajkowski, J., & Cohen, J. (2000). Locus coeruleus and regulation of behavioral flexibility and attention. In *Progress in brain research* (Vol. 126, pp. 165-182). Elsevier. doi: 10.1016/S0079-6123(00)26013-5

Awh, E., Serences, J., Laurey, P., Dhaliwal, H., van der Jagt, T., & Dassonville, P. (2004). Evidence against a central bottleneck during the attentional blink: Multiple channels for configural and featural processing. *Cognitive psychology*, *48*(1), 95-126. doi:10.1016/S0010-0285(03)00116-6

Bacon, W. F., & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. *Perception & Psychophysics*, *55*(5), 485–496. https://doi.org/10.3758/BF03205306

Baddeley, A. (1986). *Working memory.* Oxford: Clarendon.

Baddeley, A. (2010). Working memory. *Current biology*, *20*(4), R136-R140. doi: https://doi.org/10.1016/j.cub.2009.12.014

Beech, A. R., Kalmus, E., Tipper, S. P., Baudouin, J. Y., Flak, V., & Humphreys, G. W. (2008). Children Induce an Enhanced Attentional Blink in Child Molesters. *Psychological Assessment*, *20*(4), 397–402. https://doi.org/10.1037/a0013587

Bowman, H., & Wyble, B. (2007). The simultaneous type, serial token model of temporal attention and working memory. *Psychological review*, *114*(1), 38. doi: 10.1037/0033-295X.114.1.38

Broadbent, D. E., & Broadbent, M. H. (1987). From detection to identification: Response to multiple targets in rapid serial visual presentation. *Perception & psychophysics*, *42*(2), 105-113.

Cecilia, J., Galceran, J., Salvador, J., Puy, J., & Mas, F. (1994). Numerical procedures in electrochemical simulation. *International Journal of Quantum Chemistry*, *51*(6), 357–367. https://doi.org/10.1002/qua.560510604

Chartier, S., Cousineau, D., & Charbonneau, D. (2004). A Connexionist Model of the Attentional Blink Effect During a Rapid Serial Visual Presentation Task. In *ICCM* (pp. 64-69).

Chun, M. M., & Potter, M. C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental psychology: Human perception and performance*, *21*(1), 109.

Chun, M. M., & Potter, M. C. (2001). The attentional blink and task switching within and across modalities. *The limits of attention: Temporal constraints in human information processing*, 20-35.

Columbia, B., & Nagle, M. (1980). Treisman and Gelade - A feature-integration theory of attention.pdf, *136*, 97–136. https://doi.org/10.1016/0010-0285(80)90005-5

Craston, P., Wyble, B., Chennu, S., & Bowman, H. (2015). The Attentional Blink Reveals Serial Working Memory Encoding : Evidence from Virtual and Human Event-related Accessed The Attentional Blink Reveals Serial Working Memory Encoding : Evidence from Virtual and Human Event-related Potentials. *Journal of Cognitive Neuroscience*, *21*(3), 550–566.

Damsma, A., van der Mijn, R., & van Rijn, H. (2018). Neural markers of memory consolidation do not predict temporal estimates of encoded items. *Neuropsychologia*, *117*, 36–45. https://doi.org/10.1016/j.neuropsychologia.2018.04.039

De Martino, B., Kalisch, R., Rees, G., & Dolan, R. J. (2009). Enhanced processing of threat stimuli under limited attentional resources. *Cerebral Cortex*, *19*(1), 127–133. https://doi.org/10.1093/cercor/bhn062

Desimone, R., & Duncan, J. (1995). Neural Mechanisms of Selective Visual Attention. *Annual Review Neuroscience*, *18*, 193–222. https://doi.org/10.1146/annurev.neuro.18.1.193

Di Lollo, V., Kawahara, J. I., Ghorashi, S. S., & Enns, J. T. (2005). The attentional blink: Resource depletion or temporary loss of control?. *Psychological research*, *69*(3), 191-200.

Donchin, E. (1981). Surprise!… surprise?. *Psychophysiology*, *18*(5), 493-513.

Donchin, E., & Coles, M. G. (1988). Is the P300 component a manifestation of context updating?. *Behavioral and brain sciences*, *11*(3), 357-374.

Drew, T., & Shapiro, K. (2006). Representational masking and the attentional blink. *Visual Cognition*, *13*(4), 513-528. doi:10.1080/13506280544000255

Dux, P. E., Asplund, C. L., & Marois, R. (2009). Both exogenous and endogenous target salience manipulations support resource depletion accounts of the attentional blink: A reply to Olivers, Spalek, Kawahara, and Di Lollo (2009). *Psychonomic Bulletin and Review*, *16*(1), 219–224. https://doi.org/10.3758/PBR.16.1.219

Dux, P. E., & Harris, I. M. (2007). On the failure of distractor inhibition in the attentional blink. *Psychonomic Bulletin & Review*, *14*(4), 723-728.

Dux, P. E., & Marois, R. (2009). The attentional blink: A review of data and theory. *Attention, Perception, & Psychophysics*, *71*(8), 1683-1700.

Engen, H. G., Smallwood, J., & Singer, T. (2017). Differential impact of emotional task relevance on three indices of prioritised processing for fearful and angry facial expressions. *Cognition and Emotion*, *31*(1), 175–184. https://doi.org/10.1080/02699931.2015.1081873

Findlay, J. M., & Walker, R. (1999). A model of saccade generation based on parallel processing and competitive inhibition. *Behavioral and Brain Sciences*, *22*(4), 661–674. https://doi.org/10.1017/S0140525X99002150

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. Journal of Experimental Psychology: Human Perception and Performance, 18(4), 1030-1044. http://dx.doi.org/10.1037/0096-152. *Journal of Experimental Psychology: Human Perception and Performance*, *18*(4), 1030–1044. https://doi.org/http://dx.doi.org/10.1037/0096-1523.18.4.1030

Fragopanagos, N., Kockelkoren, S., & Taylor, J. G. (2005). A neurodynamic model of the attentional blink. *Cognitive Brain Research*, *24*(3), 568-586.

Gegenfurtner, K. R., & Sperling, G. (1993). Information transfer in iconic memory experiments. *Journal of Experimental Psychology: Human Perception and Performance*, *19*(4), 845. doi: 10.1037/0096-1523.19.4.845

Hodsoll, J. P., & Humphreys, G. W. (2005). The effect of target foreknowledge on visual search for categorically separable orientation targets. *Vision Research*, *45*(18), 2346–2351. https://doi.org/10.1016/j.visres.2005.03.017

Irwin, D. E., & Andrews, R. V. (1996). Integration and accumulation of information across saccadic eye movements. In T. Inui & J. L. Mc- Clelland (Eds.), *Attention and performance XVI: Information integration in perception and communication* (pp. 125–155). Cambridge, MA: MIT Press.

Itti, L., & Koch, C. (2001). Computational modelling of visual attention. *Nature Reviews Neuroscience*, *2*, 194. Retrieved from https://doi.org/10.1038/35058500

Jefferies LN, Ghorashi S, Kawahara J, Di Lollo V (2007) Ignorance is bliss: The role of observer expectation in dynamic spatial tuning of the attentional focus. Percept Psychophys 69:1162–1174.

Jolicoeur, P. (1998). Modulation of the attentional blink by on-line response selection: Evidence from speeded and unspeeded Task 1 decisions. *Memory & Cognition*, *26*(5), 1014-1032.

Jolicoeur, P. (1999). Restricted attentional capacity between sensory modalities. *Psychonomic Bulletin & Review*, *6*(1), 87-92.

Jolicoeur, P., & Dell'Acqua, R. (1998). The demonstration of short-term consolidation. *Cognitive psychology*, *36*(2), 138-202.

Jolicoeur, P., Dell'Acqua, R., & Crebolder, J. M. (2001). The attentional blink bottleneck.
Kanwisher, N. G. (1987). Repetition blindness: Type recognition without token individuation. *Cognition*, *27*(2), 117-143.

Kawahara, J. I., Enns, J. T., & Di Lollo, V. (2006). The attentional blink is not a unitary phenomenon. *Psychological research*, *70*(6), 405-413. doi: 10.1007/s00426-005-0007-5 Keil, A., & Ihssen, N. (2004). Identification Facilitation for Emotionally Arousing Verbs during the Attentional Blink. *Emotion*, *4*(1), 23–35. https://doi.org/10.1037/1528-3542.4.1.23

Keil, A., Ihssen, N., & Heim, S. (2006). Early Cortical Facilitation for Emotionally arousing targets during Attentional Blinks. *BMC Biology*, *13*, 1–13. https://doi.org/10.1186/1741-7007-4-23

Lagroix, H. E. P., Patten, J. W., Di Lollo, V., & Spalek, T. M. (2016). Perception of temporal order during the attentional blink: Using stimulus salience to modulate prior entry. *Attention, Perception, and Psychophysics*, *78*(4), 1064–1073. https://doi.org/10.3758/s13414-016-1065-z

Lagroix, H. E. P., Spalek, T. M., & Di Lollo, V. (2011). The role of observer strategy in the single-target AB paradigm. *Psychonomic Bulletin and Review*, *18*(5), 917–922. https://doi.org/10.3758/s13423-011-0121-x

Landau, A. N., & Bentin, S. (2008). Attentional and perceptual factors affecting the attentional blink for faces and objects. *Journal of Experimental Psychology: Human Perception and Performance*, *34*(4), 818. doi: 10.1037/0096-1523.34.4.818

Lawrence, D. H. (1971). Two studies of visual search for word targets with controlled rates of presentation. *Perception & Psychophysics*, *10*(2), 85-89.

Leber, A. B., & Egeth, H. E. (2006). It's under control: Top-down search strategies can override attentional capture. *Psychonomic Bulletin and Review*, *13*(1), 132–138. https://doi.org/10.3758/BF03193824

Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature*, *390*(6657), 279.

MacLeod, J., Stewart, B. M., Newman, A. J., & Arnell, K. M. (2017). Do emotion induced blindness and the attentional blink share underlying mechanisms? An event-related potential study of emotionally-arousing words. *Cognitive, Affective and Behavioral Neuroscience*, *17*(3), 592–611. https://doi.org/10.3758/s13415-017-0499-7

Mounts, J. R., Gavett, B. E. (2004). The role of salience in localized attentional interference. *Vision Research, 44*(13), 1575-1588. https://doi.org/10.1016/j.visres.2004.01.015

Nakayama, K., & Mackeben, M. (1989). Sustained and transient components of focal visual attention. *Vision research*, *29*(11), 1631-1647.

Nieuwenstein, M. R. (2006). Top-down controlled, delayed selection in the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance*, *32*(4), 973.

Nieuwenstein, M. R., Chun, M. M., van der Lubbe, R. H., & Hooge, I. T. (2005). Delayed attentional engagement in the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance*, *31*(6), 1463. doi: 10.1037/0096-1523.31.6.1463

Nieuwenstein, M. R., & Potter, M. C. (2006). Temporal limits of selection and memory encoding: A comparison of whole versus partial report in rapid serial visual presentation. *Psychological science*, *17*(6), 471-475.

Nieuwenstein, M. R., Potter, M. C., & Theeuwes, J. (2009). Unmasking the attentional blink. *Journal of Experimental Psychology: Human perception and performance*, *35*(1), 159. doi: 10.1037/0096-1523.35.1.159

Nieuwenstein, M., & Wyble, B. (2014). Beyond a mask and against the bottleneck: Retroactive dual-task interference during working memory consolidation of a masked visual target. *Journal of Experimental Psychology: General*, *143*(3), 1409–1427. https://doi.org/10.1037/a0035257

Nothdurft, H. C., & Parlitz, D. (1993). Absence of express saccades to texture or motion defined targets. *Vision Research*, *33*(10), 1367–1383. https://doi.org/10.1016/0042-6989(93)90044-W

Nothdurft, H. C. (2000). Salience from feature contrast: additivity across dimensions. *Vision Research*, *40*(10–12), 1183–1201. https://doi.org/10.1016/S0042-6989(00)00031-6

Nothdurft, H. C. (1993). Saliency effects across dimensions in visual search. *Vision Research*, *33*(5–6), 839–844. https://doi.org/10.1016/0042-6989(93)90202-8

Olivers, C. N. (2007). The time course of attention: It is better than we thought. *Current directions in psychological science*, *16*(1), 11-15.

Olivers, C. N., & Meeter, M. (2008). A boost and bounce theory of temporal attention. *Psychological review*, *115*(4), 836. doi: 10.1037/a0013395

OLivers, C. N. L., Spalek, T. M., Kawahara, J. I., & di Lollo, V. (2009). The attentional blink: Increasing target salience provides no evidence for resource depletion. A commentary on Dux, Asplund, and Marois (2008). *Psychonomic Bulletin and Review*, *16*(1), 214–218. https://doi.org/10.3758/PBR.16.1.214

Phillips, W. A., & Christie, D. F. M. (1977). Components of visual memory. *The Quarterly Journal of Experimental Psychology*, *29*(1), 117-133.

Potter, M. C. (1976). Short-term conceptual memory for pictures. *Journal of experimental psychology: human learning and memory*, *2*(5), 509.

Potter, M. C., Chun, M. M., Banks, B. S., & Muckenhoupt, M. (1998). Two attentional deficits in serial target search: the visual attentional blink and an amodal task-switch deficit. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*(4), 979.

Potter, M. C., Staub, A., & O'connor, D. H. (2002). The time course of competition for attention: Attention is initially labile. *Journal of Experimental Psychology: Human Perception and Performance*, *28*(5), 1149.

Raymond, J. E., & Brien, J. L. O. (2009). Selective visual attention and motivation. *Psychological Science*, *20*(8), 981–988. https://doi.org/10.1111/j.1467-9280.2009.02391.x

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink?. *Journal of experimental psychology: Human perception and performance*, *18*(3), 849.

Reeves, A., & Sperling, G. (1986). Attention gating in short-term visual memory. *Psychological review*, *93*(2), 180.

Ricker, T. J., Nieuwenstein, M. R., Bayliss, D. M., & Barrouillet, P. (2018). Working memory consolidation: Insights from studies on attention and working memory. *Annals of the New York Academy of Sciences*, *1424*, 8–18. https://doi.org/10.1111/nyas.13633

Robinson, A. K., Mattingley, J. B., & Reinhard, J. (2013). Odors enhance the salience of matching images during the attentional blink. *Frontiers in Integrative Neuroscience*, *7*(November), 1–6. https://doi.org/10.3389/fnint.2013.00077

Ruthruff, E., Pashler, H. E., & Klaassen, A. (2001). Processing bottlenecks in dual-task performance: Structural limitation or strategic postponement?. *Psychonomic bulletin & review*, *8*(1), 73-80.

Serences, J. (2010). Processing Channels, *17*(4). https://doi.org/10.1080/13506280802102541.Online

Sergent, C., Baillet, S., & Dehaene, S. (2005). Timing of the brain events underlying access to consciousness during the attentional blink. *Nature Neuroscience,* 8, 1391-1400.

Shapiro, K., Driver, J., Ward, R., & Sorensen, R. E. (1997). Priming from the attentional blink: A failure to extract visual tokens but not visual types. *Psychological Science*, *8*(2), 95-100.

Shapiro, K. L., Raymond, J. E., & Arnell, K. M. (1994). Attention to visual pattern information produces the attentional blink in rapid serial visual presentation. *Journal of Experimental psychology: Human perception and performance*, *20*(2), 357.

Shapiro, K. L., Raymond, J. E., & Arnell, K. M. (1997). The attentional blink. *Trends in cognitive sciences*, *1*(8), 291-296.

Shibuya, H., & Bundesen, C. (1988). Visual selection from multielement displays: measuring and modeling effects of exposure duration. *Journal of Experimental Psychology: Human Perception and Performance*, *14*(4), 591. doi:10.1037/0096-1523.14.4.591

Shih, S. I. (2008). The attention cascade model and attentional blink. *Cognitive Psychology*, *56*(3), 210–236. https://doi.org/10.1016/j.cogpsych.2007.06.001

Shih, S. I., & Reeves, A. (2007). Attentional capture in rapid serial visual presentation. *Spatial Vision*, *20*(4), 301–315. https://doi.org/10.1163/156856807780919019

Simione, L., Raffone, A., Wolters, G., Salmas, P., Nakatani, C., Belardinelli, M. O., & van Leeuwen, C. (2012). ViSA: A neurodynamic model for visuo-spatial working memory, attentional blink, and conscious access. *Psychological Review*, *119*(4), 745–769. https://doi.org/10.1037/a0029345

Soto, D., Hodsoll, J., Rotshtein, P., & Humphreys, G. W. (2008). Automatic guidance of attention from working memory. *Trends in Cognitive Sciences*, *12*(9), 342–348. https://doi.org/10.1016/J.TICS.2008.05.007

Soto, D., Humphreys, G. W., & Heinke, D. (2006). Working memory can guide pop-out search. *Vision Research*, *46*(6–7), 1010–1018. https://doi.org/10.1016/j.visres.2005.09.008

Sperling, G. (1960). The information available in brief visual presentations. *Psychological monographs: General and applied*, *74*(11), 1.

Taatgen, N. A., Juvina, I., Schipper, M., Borst, J. P., & Martens, S. (2009). Too much control can hurt: A threaded cognition model of the attentional blink. *Cognitive psychology*, *59*(1), 1-29. doi:10.1016/j.cogpsych.2008.12.002.

Theeuwes, J. (2004). No Blindness for Things That Do Not Change. *Psychological Science*, *15*(1), 65–70. https://doi.org/10.1111/j.0963-7214.2004.01501011.x

Tibboel, H., De Houwer, J., Van Bockstaele, B., & Verschuere, B. (2013). Is the diminished attentional blink for salient T2 stimuli driven by a response bias? *Psychological Record*, *63*(3), 427–440. https://doi.org/10.11133/j.tpr.2013.63.3.002

Trick, L. M., Enns, J. T., Mills, J., & Vavrik, J. (2004). Paying attention behind the wheel: A framework for studying the role of attention in driving. *Theoretical Issues in Ergonomics Science*, *5*(5), 385-424. doi: 10.1080/14639220412331298938

Treisman, A. (1986). 4. Features and Objects in Visual Processing automatically extracted from a scene are assembled into objects, 114–125.

Treisman, A. (1988). Features and objects: The fourteenth bartlett memorial lecture. *The Quarterly Journal of Experimental Psychology Section A*, *40*(2), 201–237. https://doi.org/10.1080/02724988843000104

Unsworth, N., Schrock, J. C., & Engle, R. W. (2004). Working memory capacity and the antisaccade task: individual differences in voluntary saccade control. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(6), 1302. doi: 10.1037/02787393.30.6.1302

Visser, T. A., Bischof, W. F., & Di Lollo, V. (1999). Attentional switching in spatial and nonspatial domains: Evidence from the attentional blink. *Psychological Bulletin*, *125*(4), 458.

Vogel, E. K., & Luck, S. J. (2002). Delayed working memory consolidation during the attentional blink. *Psychonomic Bulletin & Review*, *9*(4), 739-743.

Vogel, E. K., Luck, S. J., & Shapiro, K. L. (1998). Electrophysiological evidence for a postperceptual locus of suppression during the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance*, *24*(6), 1656.

Vogel, E. K., Woodman, G. F., & Luck, S. J. (2001). Storage of features, conjunctions, and objects in visual working memory. *Journal of Experimental Psychology: Human Perception and Performance*, *27*(1), 92. doi: 10.1037//0096-1523.27.1.92

Ward, R., Duncan, J., & Shapiro, K. (1996). The slow time-course of visual attention. *Cognitive psychology*.

Waters, A. J., Heishman, S. J., Lerman, C., & Pickworth, W. (2007). Enhanced identification of smoking-related words during the attentional blink in smokers. *Addictive Behaviors*, *32*(12), 3077–3082. https://doi.org/10.1016/j.addbeh.2007.05.016

Weichselgartner, E., & Sperling, G. (1987). Dynamics of automatic and controlled visual attention. *Science*, *238*(4828), 778-780. doi: 10.1126/science.3672124.

Williams, M. A., Visser, T. A., Cunnington, R., & Mattingley, J. B. (2008). Attenuation of Neural responses in primary visual cortex during the attentional blink. *Journal of Neuroscience*, *28*(39), 9890-9894. doi: 0.1523/JNEUROSCI.3057-08.2008

Wolfe, J. M. (1992). The Parallel Guidance of Visual Attention. *Current Directions in Psychological Science*, *1*(4), 124–128. https://doi.org/10.1111/14678721.ep10769733

Wolfe, J. M. (1994). Guided Search 2.0 A revised model of visual search. *Psychonomic Bulletin & Review*, *1*(2), 202–238. https://doi.org/10.3758/BF03200774

Wolfe, J. M., Cave, K. R., & Franzel, S. L. (1989). Guided Search: An Alternative to the Feature Integration Model for Visual Search. *Journal of Experimental Psychology: Human Perception and Performance*, *15*(3), 419–433. https://doi.org/10.1037/0096-1523.15.3.419

Woodman, G. F., & Vogel, E. K. (2005). Fractionating working memory: Consolidation and maintenance are independent processes. *Psychological science*, *16*(2), 106 113. doi: 10.1111/j.0956-7976.2005.00790.x